Pilot Overview Assessment of Windthrow Along Edges

and the

Efficacy of Operational Edge Pruning and Topping Treatments

at

West Island Timberlands

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Weyerhaeuser Canada Ltd.
B.C. Coastal Group
Nanaimo Timberlands Services
65 Front Street
Nanaimo, B.C.
V9R 5H9

T.P. Rollerson, Golder Associates Ltd.
C.M. Peters, CMP Biological Consulting
W.J. Beese, Weyerhaeuser Company Ltd.
Tom Whitfiedl, Weyerhaeuser Company Ltd.

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Executive Summary

The edge treatment evaluation pilot study was carried out in Weyerhaeuser's West Island Timberlands unit (WI) on the southwestern coast of Vancouver Island. The WI edge treatment blocks were located within rolling coastal plain areas and hillsides on the western flank of the Vancouver Island Mountains south of Alberni Inlet.

The overall project objectives that are partially addressed by the pilot study are to:

- Document the levels of wind damage (amount and penetration of windthrow) associated with various "leading edge" crown modification treatments.
- Evaluate the utility of using helicopter surveys to document windthrow along setting edges.
- Document the character and variability of crown modification treatments in the study area.
- Communicate results to field staff to help reduce the potential for wind damage by improving harvesting layout and edge treatments.

A total of 63,425 meters (63 km) of falling boundary was sampled. The sample plots include external setting edges and the edges of strips of retained timber within settings.

There is some indication that operational "leading edge" crown modification treatments, except for manual topping treatments, are not reducing wind damage along external boundaries; however, as the data set for these treatments is small, this conclusion should be considered tentative.

The distance that windthrow penetrates into a stand edge tends to be affected by some of the same factors that control percent windthrow. Penetration increases as percent windthrow increases. Wind damage tends to vary with changes in boundary exposure. Both penetration distances and percent windthrow are less on lee boundaries than on windward boundaries.

Wind damage tends to increase with increases in average stand height and wind exposure irrespective of treatment. In many cases changes in other factors such as the width of retained strips and the boundary-slope geometry appear to affect the degree of wind damage more than pruning or topping treatments.

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1.0 Introduction

The current survey methodology for the Variable Retention Windthrow Monitoring Study (Rollerson et al., 2003) has been restricted to ground surveys. As ground surveys can be time-consuming, there is a need to determine if more rapid overview assessments can be used to document the amount of windthrow along setting edges and in retention patches. This pilot study combined evaluation of the utility of a helicopter overview assessment approach with an assessment of the efficacy of operational helicopter pruning and topping and manual topping as methods to reduce windthrow along setting edges.

Leading edge pruning and/or topping has been carried out in a total of about 60 blocks in Weyerhaeuser's West Island Timberlands Franklin River Operation over the period 2001-2002. At this time there has been no systematic assessment of the efficacy of these treatments compared to untreated edges. As part of an ongoing program of adaptive management, it is important to carry out periodic assessments of the degree to which these treatments have been effective in reducing the amount of windthrow compared to non-treated edges.

A previous study by Rowan et al. (2001) looked at the efficacy of helicopter pruning treatments in a moderate number of long-term study areas that were established to evaluate the utility of topping, pruning and feathering treatments along setting edges. The results of that study indicated a 40 percent reduction in windthrow along edges where pruning and topping had been carried out in comparison to the controls.

The current overview assessment attempts to extend Rowan's earlier work and focus on these techniques on the southwest coast of Vancouver Island. In this case, unlike Rowan's study, the pruning and topping are a result of operational not experimental treatments, the pruning has been done primarily by helicopter not manual methods; and, a limited amount of helicopter topping has been done; but, it has been restricted to second-growth stands. Rowan's study included three distinct pruning and topping treatments (e.g., leading edge and 50% distribution or 100% distribution within a 30-meter deep treatment zone). At this time we do not have a good appreciation of the range in character of the operational helicopter pruning treatments that have occurred in the West Island Timberlands, so part of the current study entails documentation of the character and variability of the operational helicopter pruning treatments.

2.0 Project Objectives

The project objectives are to:

- Document the levels of wind damage (amount and penetration of windthrow) associated with various "leading edge" crown modification treatments.
- Evaluate the utility of using helicopter surveys to document windthrow along setting edges.

- Document the character and variability of crown modification treatments in the study area.
- Communicate results to field staff to help reduce the potential for wind damage by improving harvesting layout and edge treatments.

3.0 Methodology

The study consisted of a limited number of helicopter and a much larger number of ground traverses of falling boundaries in 26 harvest blocks selected from a total of 60 settings where pruning and topping or feathering operations have been carried out over the past two years. Based on the results of preliminary helicopter traverses, a follow-up ground validation study was implemented. The setting edges have experienced severe wind events over the winters of 2001 and 2002.

The original intention was to use a helicopter for the entire study so that reasonably accurate determinations of the presence or absence of pruning could be done effectively and efficiently. It can be difficult to see from the ground where and if trees have been pruned, and the potentially large number of edges to be evaluated was thought to limit the use of slower ground traverse methods.

Initial assessments of the utility of the helicopter approach indicated that this method was useful for obtaining a general impression of the extent and character of the windthrow and pruning and topping treatments associated with setting edges. Helicopter traverses of setting edges were not suitable, however, for obtaining consistent data on the amount of windthrow or the extent and character of pruning and topping treatments. Consequently, the majority of the sampling was done using ground traverses along setting edges.

3.1 Sampling Design

3.1.1 Sample segment delineation and plot selection

All external falling boundaries and boundaries along retained strips of timber in the selected blocks were sampled, including both treated and untreated edges. The sampling occurred one to two years after the edges had been treated. Some of the blocks had experienced only one winter wind season prior to treatment. In general, edges that had already experienced windthrow were not treated.

It is necessary to partition or stratify the falling boundaries into segments or sample plots in a systematic fashion so that the plot data will be suitable for statistical analysis. Since the study is retrospective in nature, there were two obvious choices available for the delineation of plots. We could create equal length plots or we could accept unequal length plots. Forest stands and terrain do not conveniently split apart into equal sized pieces, therefore, it is logistically easier to deal with unequal sized plots when carrying out rapid field-surveys. For the purposes of the pilot study, we decided to use unequal length plots, and then use a length-based weighting approach during the data analysis phase to accommodate differences in plot size and to ensure that the central tendency of the sample population was accurately estimated.

Each boundary edge if it was large enough, was stratified into distinct and relatively homogeneous stand, geomorphic and/or geometric “entities” (segments). This stratification approach resulted in the creation of unequal length plots or ‘sample segments. This sampling scheme is similar to the approach used for the Weyerhaeuser variable retention windthrow monitoring study and an earlier study of windthrow in riparian reserves done for Western Forest Products on northern Vancouver Island (Rollerson and McGourlick, 2001).

Stratification or separation was based on the following field criteria:

- Significant changes in the orientation (aspect) of a falling boundary (e.g., a 30° change in boundary orientation).
- Visible and significant changes in slope angle, terrain (surficial materials), slope morphology, soils, or soil drainage along a falling boundary.
- Changes in forest (stand) type (species composition or height) along a boundary.
- Type of edge treatment (untreated, feathered, topped or pruned, etc.).
- Changes in the amount or character of windthrow did not affect sample selection.
- The sample segments (plots) are generally a minimum of 50 metres long; however, shorter segments that are very distinctive are sampled as separate plots. Short segments similar to adjacent areas were incorporated into the most similar adjacent plot.

A limited number of segments less than 50 metres long were sampled because they were significantly different than the adjacent boundary segments.

The stratified, unequal length or unequal area samples (plots) improved sampling efficiency and ensured that any visible environmental differences that could potentially exert a significant effect on windthrow response were sampled. For example, random or systematically located plots that fall across significant changes in soil type or boundary orientation could well confound any subsequent analysis if these factors strongly affect windthrow susceptibility. Since the two important wind damage variables (percent windthrow and the distance windthrow penetrates into a stand) should not be affected by sample segment length, we did not feel that differences in the length of the plots would significantly affect the outcome of the study. Additionally, some terrain/soil types are inherently quite variable over relatively short distances so sampling the full length of such “strata” should generate a more representative estimate of the amount windthrow occurring within these more heterogeneous terrain/soil types. For the objective of estimating cumulative windthrow along falling boundaries, unequal length/ sampling segments work as well as equal length plots.

3.2 Data Collection

3.2.1 Field data collection

In order to streamline data collection, we did not collect specific data on the individual trees windthrown or standing. Instead, we tallied windthrown versus standing trees or in the case of areas of extensive windthrow, we made visual estimates of the amount of windthrow present based on nominal class estimates in 5% or 10% intervals for the first 25 metres into a stand edge. Where limited numbers of trees were windthrown, it proved relatively efficient to count (tally) the number of standing and windthrown trees. Similarly, we visually estimated the depth of penetration of windthrow into the stand edge and the approximate primary and secondary orientations of windthrown trees in each plot. The orientations of individual trees were recorded when there were a limited number of windthrow stems. We used a qualitative wind exposure class system, or ranking matrix (Appendix III, Figure 1), to represent the vulnerability of boundaries that are subject to winds from more than one direction. Windthrow percentages were based on the merchantable stems in a stand; small, non-merchantable saplings and advanced regeneration were not tallied. We recorded the stand edge treatments or lack of treatment as they occurred along falling boundaries. We estimated the average stand height for each sample plot using a hip chain and clinometer.

3.2.2 Office map work methodology

There were a number of mapping procedures performed for each site. First, the windthrow assessment plots along the external block edge were coded on the map and the length of the plots was measured. A histogram was then developed using the windthrow orientations (azimuth) collected for each plot in the block, and the two most numerous (dominant) windthrow orientations were determined. These represent the estimated primary and secondary wind directions for each block. A protractor, ruler and transparency with boundary exposure types outlined in degrees were used to determine the boundary exposure class of each plot based on the two dominant wind directions. The center of the transparency was placed over the middle of the boundary edge orientated so that the windward arrow was perpendicular to the boundary edge. A protractor was then placed on top, orientated parallel to the north lines of the map, with the center of the protractor over the center of the transparency. The boundary exposure type was then determined by the quadrant of the transparency that the wind direction passed into after it went through the boundary edge.

For each plot that had windward or windward diagonal boundary exposures, the fetch distance[1] was measured and the fetch type was determined. Fetch type and distance

[1] Fetch, is measured as the distance from the center of a sampling strip on an external boundary, patch edge or retained group of trees to the upwind external block boundary in the direction of the primary and secondary windthrow orientations in a block. Lee boundaries and parallel boundary exposures are assigned a nominal fetch distance of zero metres. For purposes of this analysis, the primary and secondary fetch distances were combined to derive an “cumulative fetch distance” [cumulative fetch = (fetch1 + fetch 2)] as a semi-quantitative way of recognizing that wind forces may have been applied to a boundary by winds from more than one direction. To simplify data analysis and allow for the large variation in fetch distances, fetch distances were combined into 8 categories ranging from zero metres to greater than 500 metres.

were determined using the primary and secondary wind directions for each block. Finally, the stand height upwind of the plot was tabulated using the stand heights recorded for the plot upwind of the exposed boundary for each fetch direction. Because of the limited sample sizes for a number of treatment plots, fetch distance, fetch type and upwind stand height were not used in the analysis. A comparison of fetch distance and wind damage for untreated edges was made and is presented at the end of the Appendix II (Figures U7 and U8).

All data was collected on waterproof paper forms in the field. Office measurements were entered into an Excel spreadsheet and imported into SPSS for statistical analysis.

4.0 Study Areas for the Pilot Project

The edge treatment pilot project was carried out in 26 harvested blocks in Weyerhaeuser's West Island Timberlands. The sample areas for 2003 were located along the coastal plain on the southwest coast of Vancouver Island and on hillsides on the western flanks of the Vancouver Island Ranges within TFL 44.

The plots generally occur within the Submontane Very Wet Maritime Variant of the Coastal Western Hemlock Zone (CWH). This particular biogeoclimatic unit is one of the most extensive on Vancouver Island. A limited number of blocks may be located within the Southern Very Wet Hypermaritime Variant, the Montane Very Wet Maritime Variant, and the Very Dry Maritime Subzone of the CWH.

The sample plots are reasonably well distributed topographically, occurring on coastal plains, low hills, moderate hills, high hills and broad valleys.

5.0 Data Analysis

Analysis of the pilot project data consisted of simple tabular and graphical analysis to identify trends in the data and to evaluate the suitability of the approach and data for use in future studies. To obtain valid means for percent windthrow, the unequal length plots were weighted using a length-based weighting factor. The nominal length used to develop the length-based weighting factor was set at 50 meters.

Due to the retrospective nature of this study, the treatments vary significantly among the cutblocks sampled (Table 1). To minimize variation in the data due to changes in geographic location and stand characteristics, the data was partitioned by cutblock into a series of treatment types or categories (Table 5). For any given type of treatment, only the untreated plots ("controls") from those particular blocks were used for the comparison of treated to untreated plots. In some situations where there are only a limited number of harvest blocks and treatment or "control" plots available, the results of the analysis should be viewed with caution. In some cases no definitive conclusions can be reached until we have more data for specific treatment types.

To minimize the risk of creating false comparisons or drawing false conclusions, we compared and if necessary filtered the data by plot strata (e.g., retained strips versus external block boundaries), boundary (wind) exposure class, and stand height because we assumed that there might be significant differences associated with these factors that had little to do with the actual treatments. In this regard, a number of comparisons for the untreated plots are included at the end of the graphical analysis appendix to allow the reader to evaluate how windthrow varies with changes in these factors.

6.0 Results and Discussion

In order to simplify the analysis and the discussion of results, we separated the different windthrow control strategies employed along falling boundaries into a series of treatment types: heli-pruning, manual topping, heli-topping and feathering. Where sufficient samples existed, the relationship between treated and untreated falling boundary segments was evaluated. In the case of feathered edges, the sample size was considered to be too small to evaluate at this time. We also, tried to explore relationships between the degree of wind exposure and the interaction between treatment and the location of the boundary relative to slope geometry. In the discussion that follows, the term “wind damage” is used to refer to both the amount (percent) of windthrow and the distance windthrow penetrates into a stand or retained strip of timber. The study did not consider the effect of edge treatments on retained groups or patches of timber.

It is important to remember when interpreting the results of the study that this is a reconnaissance evaluation of the efficacy of “leading edge” windthrow control treatments as they were applied. We did not compare the planned treatments to the actual treatments.

The pilot study is an evaluation conducted at the stand level not the individual tree level; it does not address the question of whether or not crown modification treatments affect the windthrow potential of individual trees.

By way of example, block 655 had 20 trees pruned over 165 meters of boundary edge, or about one pruned tree for every 8 meters of boundary. Block 9624 had 118 pruned trees over 930 meters, or one pruned tree every 8 meters. Block 873317 had 31 pruned trees over 320 meters of boundary edge or about one pruned tree every 10 meters, and block 7836 had 45 pruned trees over 645 meters or about pruned tree for every 14 meters of boundary edge. The average for these four blocks is about one tree pruned for every ten meters of boundary edge, so clearly not all trees along the stand edge were treated. Our general observation is that manual pruning treatments resulted in a slightly higher number of treated trees per meter of boundary. No other specific information on the frequency of treatment was collected during the course of the study and would have been difficult to determine in areas of extensive windthrow because of stem breakage and other damage that occurs when the trees are windthrown.

6.1 Windthrow Relationships for Heli-pruning Treatments

For these comparisons we first separated the data set into plot strata. The two strata that appeared to have a reasonable number of samples for both heli-pruning and no treatment were external block boundaries and retained strips greater and less than 50 meters wide. We separated these into two groups (external boundaries and retained strips) because we expected higher amounts of windthrow in retained strips than along external boundaries.

6.1.1 Heli-pruning along external block edges

For the external boundary sample, we filtered out those plots with estimated average stand heights less than 30 meters high as these shorter stands were not present in the heli-pruned sample. We next checked to see if there were obvious differences in the distribution of samples with changes in boundary exposure (i.e., windward versus lee, etc.). Inspection of Figure A1 suggests that some differences exist but that these are not obviously significant, and in any case, it is not clear from the distribution of samples displayed in Figure A1 that there is any useful way to further filter the data by wind exposure class. There were some limited differences in boundary-slope geometry categories between treated and untreated plots that were not filtered out of the data set. These differences could affect the results discussed below.

The comparison run on this data (Figures A2 to A5 and Table 6) indicates that heli-pruning of external block edges is associated with windthrow on the order of 20 percent compared to 11 percent for untreated external block edges. This difference is significant at the 0.02 and 0.001 levels of significance respectively for Mann-Whitney and T-test comparisons. Comparisons of the difference in windthrow penetration for heli-pruned versus untreated edges show no significant differences for windthrow penetration between treatments. Windthrow penetration averages about 10 meters for both treatments.

6.1.2 Heli-pruning along the edges of retained strips

This comparison considered retained strips that were less than and greater than 50 meters wide. As the sample did not contain both treated and untreated samples for strips narrower than 50 meters wide (Figure A8), the comparison with untreated edges could only be carried out for the wider strips. We would expect significantly more windthrow along both treated and untreated edges on narrow compared to wider retained strips (see Figure U9); but, this assumption cannot be evaluated for treated strips until more data is available. In order to improve the comparison of treated to untreated plots, we filtered the data to exclude stand heights less than 30 meters as no stands less than 30 meters tall were included in the treated sample.

The small amount of data that is available for retained strips greater than 50 meters wide indicates that the amount of windthrow along heli-pruned strip edges is comparable to or higher than that along untreated strip edges (Figure A9 and Table 7). The degree of windthrow penetration into the retained strips appears slightly greater for heli-pruned than untreated edges (i.e., 24 versus 23 meters). We would caution that this is a very small sample and that it is quite possible that there are differences in the stand characteristics or wind environment of the treated and untreated strip edges that are affecting the amount of windthrow present. As noted above, we did filter the data to remove estimated average stand heights less than 30 meters tall, to ensure that the untreated edges did not contain some shorter stands. Comparison of the average stand heights of the plots in the treated and untreated strips indicated that the untreated stands were slightly taller than the treated stands (Figure A13). Some of the retained strips were only pruned along one edge, as pre-harvest windthrow assessments indicated winds from only one dominant direction. Our post-harvest assessment, however, indicates winds from more than one direction in a number of cases. Pruning on only one side of the retained strips may have affected the degree of windthrow and confounded the study results. In the case of strips greater than 50 meters wide, the average windthrow penetration distances recorded indicate that windthrow does not always penetrate completely through these strips.

6.1.3 Manual topping along external block edges

As for heli-pruned areas, the population of manually topped areas was split into external block edges and retained strips. All plots with estimated average stand heights less than 30 meters were excluded from the analysis, as were plots along lee boundaries because no lee boundaries were manually topped. Similarly, only flat, gully/scarp edge, lateral and uphill boundary-slope geometry categories were included in the analysis, as only these categories contained plots where topping had been carried out (see Appendix III for descriptions of these categories).

The analysis indicates slightly lower amounts of windthrow associated with manually topped edges than untreated edges (10% versus 13%), but these differences do not appear to be statistically significant (Figure A15 and Table 8). Similarly the distance that windthrow penetrates into stands along the edges of harvested blocks is slightly less along boundaries were manual topping has occurred, but again the values are not significantly different (Figure A19 and Table 8).

The means (error bar) plots presented in Figures A16, A17, A20 and A21 indicate that the amount of wind damage increases from lee to windward boundaries or from boundaries with a lower to a higher wind exposure ranking. This trend is more pronounced for untreated boundaries, indicating that manual topping results in a greater reduction in wind damage when applied to windward boundaries. A similar relationship is apparent with boundary-slope geometry categories, with a greater reduction in wind damage being achieved with certain boundary geometries than others (Figure A18 and A22).

Although topping results in less wind damage along gully or escarpment edges, it does not prevent windthrow. In these areas, which are often very vulnerable to windthrow, other windthrow control strategies, such as setbacks, may need to be employed in addition to edge treatments.

6.1.4 Manual topping along the edges of retained strips

As for the manual topping comparison along external boundaries, all plots with estimated average stand heights less than 30 meters were excluded from the analysis. All boundary exposure categories except for windward diagonal boundaries were excluded from the analysis as no other exposure categories contained topping treatments. For the same reason, only gully/scarp edges and lateral, boundary-slope geometry categories were included in the analysis. The lateral boundary sample did not include any untreated edges (Figure A24) but this category was retained to maximize the number of treated samples included in the analysis. Due to of the small number of samples, both narrow and wide strips were included in the same analysis.

When comparing the values in Table 9 and the distributions displayed in Figures A23 and A26, little is apparent in the way of significant differences in windthrow damage between the manually topped and untreated plots. Neither T-tests nor the Mann-Whitney test show significant differences between treatments for this comparison. There does appear to be a substantive difference in the amount of windthrow between narrow (<50 meters) and wide (>50 meters) strips. Narrower strips experience higher levels of wind damage (Figure A23). The error-bar plots indicate insignificant to minor differences in wind damage among the treated plots for different categories of boundary-slope geometry (Figures A24 and A27), but the small sample size means that this interpretation should be viewed with caution. Figure 25 suggests that there may have been greater amounts of windthrow along treated edges along narrow strips located in gullies or along scarp edges.

6.1.5 Heli-topping along external boundaries and edges of retained strips

For this comparison, because of the small sample, all of the plots were retained irrespective of stand height (Figure A30). The stand heights appear to be somewhat comparable for the two available plot strata (external edges and wide strips) that have both treated and untreated plots; therefore, we think that this approach is reasonable. Only three categories of boundary-slope geometry (flat, gully/scarp edge and lateral edges) had both treated and untreated samples, so only these categories were used for the comparison.

The indications from this analysis of a relatively small sample set (Figures A31 and Table 10) are that heli-topped edges are associated with higher amounts of windthrow than untreated edges (35% versus 13%). Similarly, the depth that windthrow penetrates into a stand edge or wide retained strip (Figure A35) appears to be greater for heli-topped edges than untreated edges (16 meters versus 9 meters). The percent windthrow values for the combined sample are significantly different with both a T-test and a Mann-Whitney test (Table 10). The windthrow penetration distances are not significantly different for either test.

Inspection of Figures A32 through A38 indicates that the amount of windthrow, both for treated and untreated plots, varies between both external edges and the edges of wide retained strips of timber, with much higher levels of wind damage along the retained strips. Similarly, changes in boundary-slope geometry category are reflected in a change in the amount of windthrow damage. Plots located along gully or scarp edges show the highest windthrow rates both for treated and untreated edges. We should note that all the retained strips occur along gully or scarp edges (Figures A34 and A38). In this particular comparison, the differences between strata and boundary-slope geometry categories appear much greater than the differences between treatments. We might be inclined to argue for this particular comparison that varying the location of falling boundaries in the landscape effects greater control over windthrow damage than edge treatment. Certainly, boundary location appears equally as important as treatment.

We stress that the sample sizes are small, particularly for the heli-topping sample. Also, even though the sample plots are from the same harvest blocks, the treated and untreated plots may not have comparable stand or environmental characteristics. Consequently, these results may not stand the test of time or a larger sample and so should be applied with caution.

6.1.6 Windthrow along untreated edges

A limited amount of graphical analysis was carried out for the entire sample population of untreated edges. This analysis is presented in Figures U1 though U9. This analysis is not evaluated in detail as this was not the focus of the pilot study, but the general trends in the data are as follows.

There is a general trend of increasing wind damage as average stand height increases (Figures U1 and U2). Figures U3 and U4 indicate that wind damage increases as the wind exposure index increases[2]. Wind damage varies with boundary-slope geometry category, with boundaries located along gully and scarp edges experiencing some of the higher wind damage values. This is a phenomena observed in other areas as well (Rollerson and McGourlick, 2001). Boundaries on steeper hillslope areas that run perpendicular to the hillslope contours also tend to have higher rates of wind damage. Increases in cumulative fetch distance tended to correspond to higher rates of wind damage (Figures U7 and U8). Finally, there appears to be variation in the amount of windthrow with change in plot strata. Narrow, retained strips of timber and peninsulas of timber, which also tend to be fairly narrow, experienced the highest percentages of windthrow (Figure U9).

7.0 Summary and Conclusions

In this section we focus on the more obvious and definitive trends in the data. The reader who is interested in some of the more obscure trends in the data will need to spend time inspecting the tables and plots provided in the appendices.

[2] The windthrow index is a qualitative measure or ranking of the apparent wind force experienced by a boundary based on windthrow orientations – see Appendix III. These index numbers usually range from two to nine, but an oversight in a data recoding routine, due to a few missing values, resulted in a slightly wider range of ranking numbers than normal.

The first observation we can make is that some treatments were located along falling boundaries that proved to have lee or parallel wind exposures; and as a consequence, windthrow rates were low irrespective of the type of treatment. We would suggest that more detailed assessment of historical windthrow patterns in proposed harvest areas should reduce the chance of treating areas where windthrow rates prove to be low.

Similarly, we noted that a number of boundaries both treated and untreated were located along the break in slope at the edges of gullies or escarpments. These are typically areas where windthrow is more severe, especially along windward boundaries. There is little indication in the data that treating these edges significantly reduced the degree of windthrow. We would suggest that because of the potentially significant consequences of windthrow along gullies or stream escarpments, windward falling boundaries be set back 15 to 20 meters from the edges of these features, especially were logging will occur on both sides of the feature. These setbacks may or may not reduce the amount of windthrow along falling boundaries but should reduce the likelihood that windthrow will penetrate to steep escarpments and/or gully sidewalls. We have observed, from time to time, that debris slides and occasionally debris flows can occur in association with windthrow along the edges of steep gully walls and stream escarpments.

Manual topping appears more successful in the prevention of windthrow than heli-pruning and heli-topping. This finding suggests that more of the effective sail or crown mass may be removed with manual pruning. It may be that heli-pruning will be more successful if more of the crown is removed during treatment.

Observations on the ground during the edge survey indicated that some edges though coded on the setting maps as being pruned only contained limited areas of actual treatment. This observation may account for some of the lack of difference between treated and untreated edges. Similarly, it was noted that in many cases not all trees along a given boundary segment were treated. In a number of these cases, residual untreated trees were more often windthrown than treated trees. These situations were not tabulated in any systematic fashion, so we are not able to do more than make these qualitative observations.

The general impression given by the results of this pilot study is that pruning and topping treatments as they are currently applied are not resulting in a significant reduction in the amount of windthrow except in a limited number of cases. This conclusion needs to be tempered with the understanding that the pruning and topping treatments were not set up in tandem with true controls; consequently, the treatment to untreated edge comparisons are as likely to have been “apples to oranges” as “apples to apples.” That said, other trends observed in the data (e.g., more windthrow on windward than lee boundaries) do make sense, so the treated to untreated edge comparisons may reflect reality.

8.0 Recommendations for Future Monitoring

As was noted in Section 6, in some cases there were only a limited number of treated and untreated plots that were possibly suitable for comparison. Given that it is not entirely clear that pruning is or is not a successful treatment, we recommend that untreated control plots be systematically inserted along boundaries where pruning or topping takes place. Embedding controls along falling boundaries will ensure that in the future, it will be possible to make direct comparisons between treated and untreated edges.

Consideration should also be given to carrying out a limited study where treated and untreated trees in a selected set of plots are marked near the ground. This will allow more definitive evaluation of the observation noted above that individual treated trees were less likely to be windthrown than individual, untreated trees.

We recommend that a slightly larger set of attributes be recorded to allow for better identification of comparable treated and untreated plots. For example, it is quite possible that the comparisons carried out included samples with varying types of stand structure or dominant species. Similarly, we may have been comparing treated units on steep slopes to untreated units on gentle slopes. Expanding the attribute data set slightly would maintain consistency in the data and limit the risk of “apple to orange” comparisons.

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Appendix I
Tabular Analysis, Year 2003 Data

Table 1a. Distribution of blocks by and numbers of plots by treatment type.

Block	Feathered	Heli-pruned	No treatment	Topped (manual)	Topped (heli)	Totals
710			23	2		25
777		2	11			13
1756			17		1	18
5769			36		1	37
6865		2	20			22
6866		2	14			16
7530			11	1		12
7550	2		16			18
7570	1		19			20
7578			14	4		18
7651			23	2		25
7660			22	1		23
7812		2	24			26
7834		1	29			30
7836		6	11			17
8655		1	21		3	25
8696			5	2		7
8710			28	6		34
8719		8	9			17
8755			13	2		15
9624		7	9			16
9659		3	16			19
9739		9	24			33
9794		1	21			22
21149		3	9			12
43215		2	2			4
Total	3	49	447	20	5	524

Table 1b. Plot lengths (meters) by treatment type summary.

Treatment	Sum	N	Mean	Std. Dev.	Max	Min
feathered	315	3	105	30	70	125
heli-pruned	4780	49	98	35	40	200
heli-topping	500	5	100	46	50	150
manual topping	2420	20	121	62	30	260
no treatment	55410	447	124	51	35	380
Total	63425	524	121	51	30	380

Table 2. Distribution of sample plots by plots strata and boundary exposure 1.

Strata	L	LD	P	WD	W	Totals
bulge	5	3	1	7	1	17
external edge	43	106	87	107	51	394
peninsula				1		1
patch edge	4	4	4	11	3	26
strip	3	9	6	10	7	35
wide strip	9	8	12	17	5	51
Totals	64	130	110	153	67	524

Table 3. Distribution of sample plots by treatment type and boundary exposure 1.

Treatment	L	LD	P	WD	W	Totals
Feathered			1	2		3
Heli-pruned	6	10	7	10	16	49
None	57	118	100	127	45	447
Topped (manual)		2	2	10	6	20
Topped (heli)	1			4		5
Totals	64	130	110	153	67	524

Table 4. Distribution of sample plots by block and boundary exposure 1.

Block	L	LD	P	WD	W	Totals
710	6	5	4	6	4	25
777	1	4	2	3	3	13
1756	1	4	7	3	3	18
5769	3	8	8	16	2	37
6865	2	8	4	5	3	22
6866	2	2	4	5	3	16
7530		2	5	3	2	12
7550	3	2	5	6	2	18
7570	1	6	4	7	2	20
7578	1	6	4	5	2	18
7651	5	5	3	8	4	25
7660	1	6	10	4	2	23
7812	2	4	5	10	5	26
7834	4	10	3	10	3	30
7836	4	4	3	2	4	17
8655	3	8	3	11		25
8696	1	1	3	2		7
8710	2	12	5	11	4	34
8719	1	6	3	3	4	17
8755	4	2	2	5	2	15
9624	3	4	4	2	3	16
9659	4	4	2	6	3	19
9739	5	7	9	8	4	33
9794	3	5	5	8	1	22
21149	2	3	2	3	2	12
43215		2	1	1		4
Totals	64	130	110	153	67	524

Table 5. Summary of blocks by treatment types occurring in each block.

(Note that untreated plots dominate in every block – see Table 1.)

Block	Feathered	Heli-pruned	Manual topping	Heli-topping	Heli-topping & prunning	Totals
710			25			25
777		13				13

1756				18		18
5769				37		37
6865		22				22
6866		16				16
7530			12			12
7550	18					18
7570	20					20
7578			18			18
7651			25			25
7660			23			23
7812		26				26
7834		30				30
7836		17				17
8655					25	25
8696			7			7
8710			34			34
8719		17				17
8755			15			15
9624		16				16
9659		19				19
9739		33				33
9794		22				22
21149		12				12
43215		4				4
Total	38	247	159	55	25	524

Table 6. Wind damage summary for external setting edges for heli-prunning.

Factor	Treatment type	N weighted	Mean	Std. Deviation	Std. Error Mean
% windthrow**	heli-pruned	46	20%	24%	4%
	no treatment	330	11%	16%	1%
Windthrow penetration*	heli-pruned	46	11m	10m	1m
	no treatment	330	10m	11m	1m

* Not significantly different.

**Significantly different at the 0.01 level of significance for both the Mann-Whitney and T-test.

Table 7. Wind damage summary for retained strips for heli-prunning.

Factor	Treatment type	N weighted	Mean	Std. Deviation	Std. Error Mean
% windthrow**	heli-pruned	5	42%	16%	8%
	no treatment	4	6%	5%	2%
Windthrow penetration*	heli-pruned	5	24m	5m	3m
	no treatment	4	23m	18m	9m

*Not significantly different for the Mann-Whitney but significantly different with a T-test.

**Significantly different at the 0.01 level of significance for both the Mann-Whitney and T-test.

Table 8. Wind damage summary for external setting edges for manual topping.

Factor	Treatment type	N weighted	Mean	Std. Deviation	Std. Error Mean
% windthrow*	manual topping	37	10%	14%	2%
	no treatment	216	13%	18%	1%
Windthrow penetration*	manual topping	37	6m	7m	1m
	no treatment	216	9m	9m	1m

*Not significantly different for the Mann-Whitney or T-test.

Table 9. Wind damage summary for retained strips for manual topping.

Factor	Treatment type	N weighted	Mean	Std. Deviation	Std. Error Mean
% windthrow*	manual topping	10	8%	5%	1%
	no treatment	8	7%	3%	1%
Windthrow penetration*	manual topping	10	11m	3m	1m
	no treatment	8	4m	2m	1m

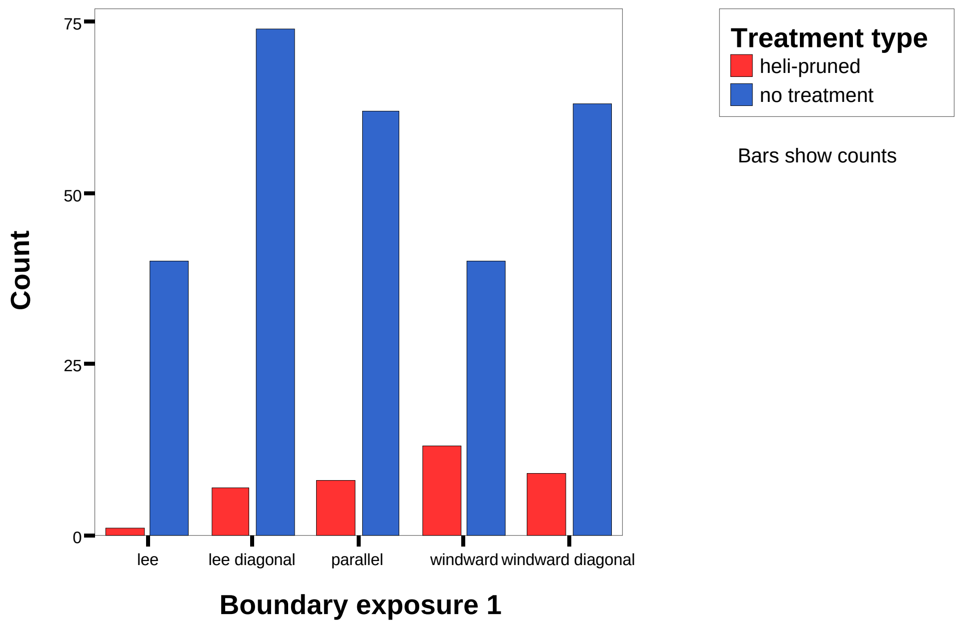
*Not significantly different for the Mann-Whitney or T-test.

Table 10. Wind damage summary for heli-topping.

Factor	Treatment type	N weighted	Mean	Std. Deviation	Std. Error Mean
% windthrow	heli-topping	9	35%	31%	10%
	no treatment	45	13%	18%	3%
Windthrow penetration	heli-topping	9	16m	12m	4m
	no treatment	45	9m	9m	1m

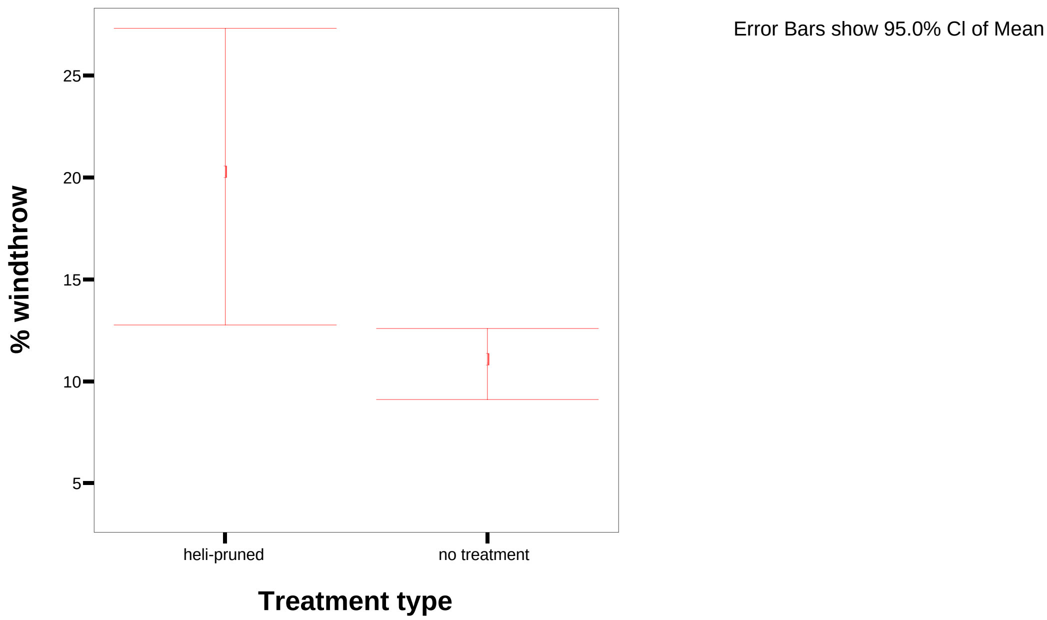
Appendix II
Graphical Analysis

Note: Any number of samples (N) tabulated on any of the plots showing percent windthrow or penetration values are the weighted number of pseudo-replicate samples not the true number of samples.



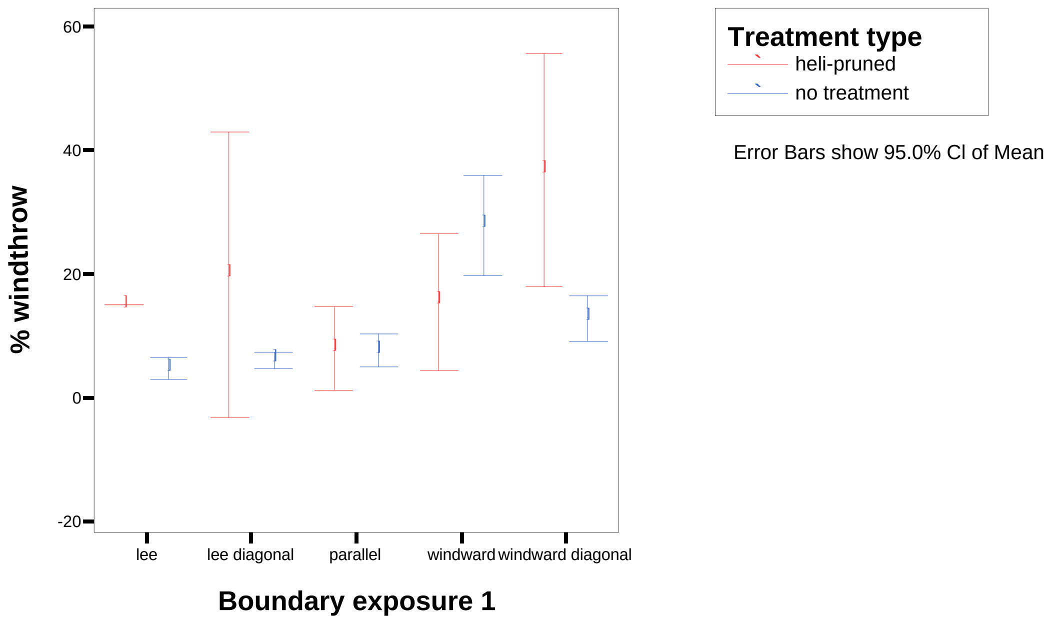
Average stand heights >30 m. Cases weighted by length-based weighting factor.

Figure A1. **Distribution plots by wind exposure class for external block edges.**



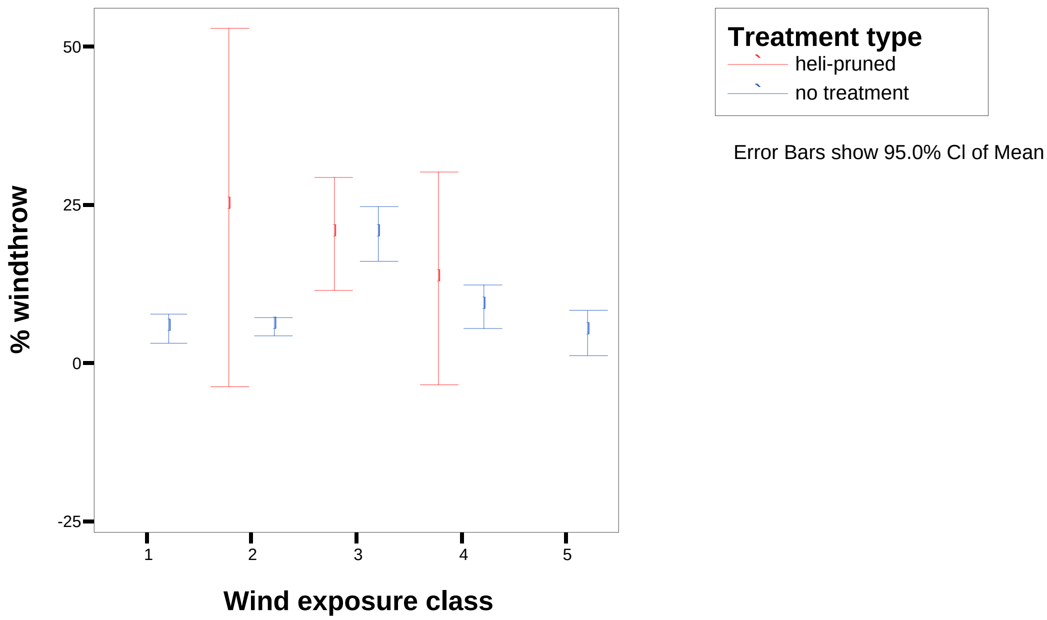
Average stand heights >30m. Cases weighted by length-based weighting factor.

Figure A2. Windthrow percentages for heli-pruned plots along external edges.



Average stand heights >30m. Cases weighted by length-based weighting factor.

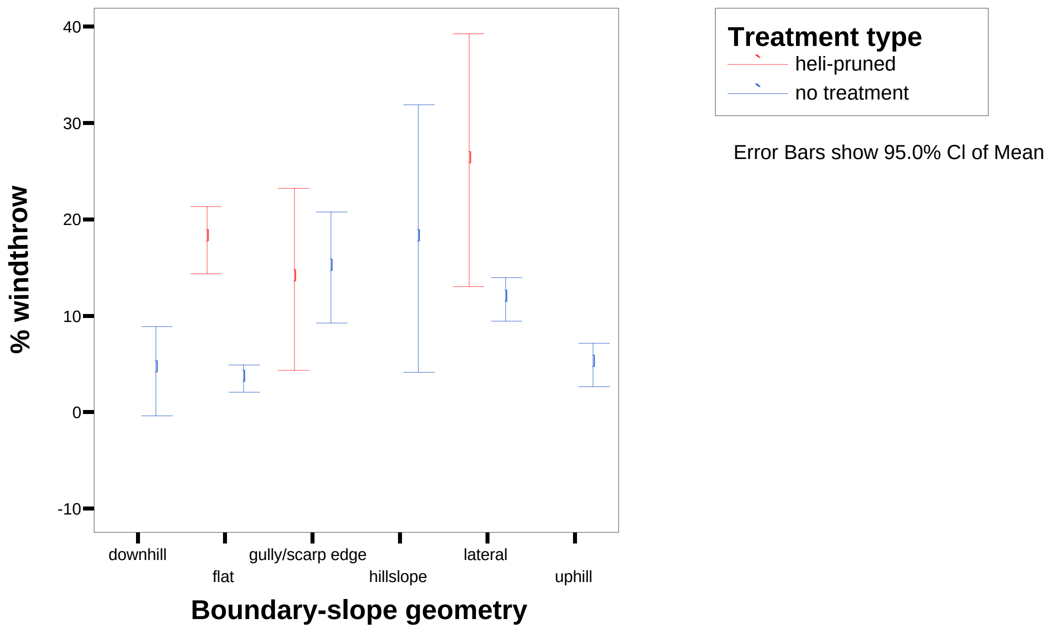
Figure A3. Percent windthrow by treatment by boundary exposure classes along external block edges.



Average stand heights >30m. Cases weighted by length-based weighting factor.

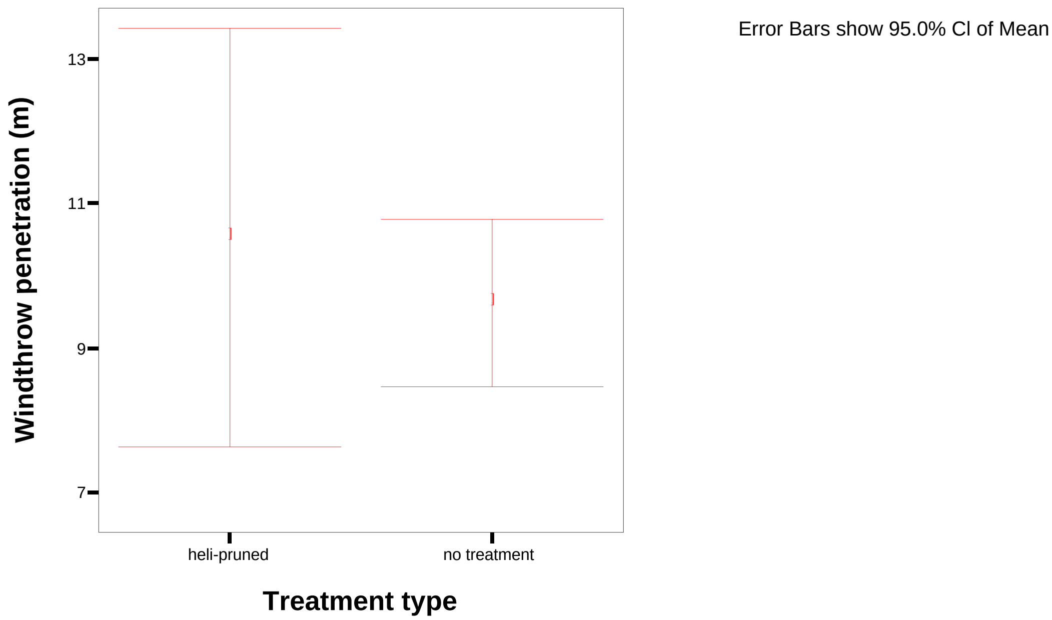
Figure A4. Percent windthrow versus wind exposure class – external block edges.

(*Note*: Wind exposure class is effectively the same metric as the wind exposure index, but 10 classes are collapsed into 5.)



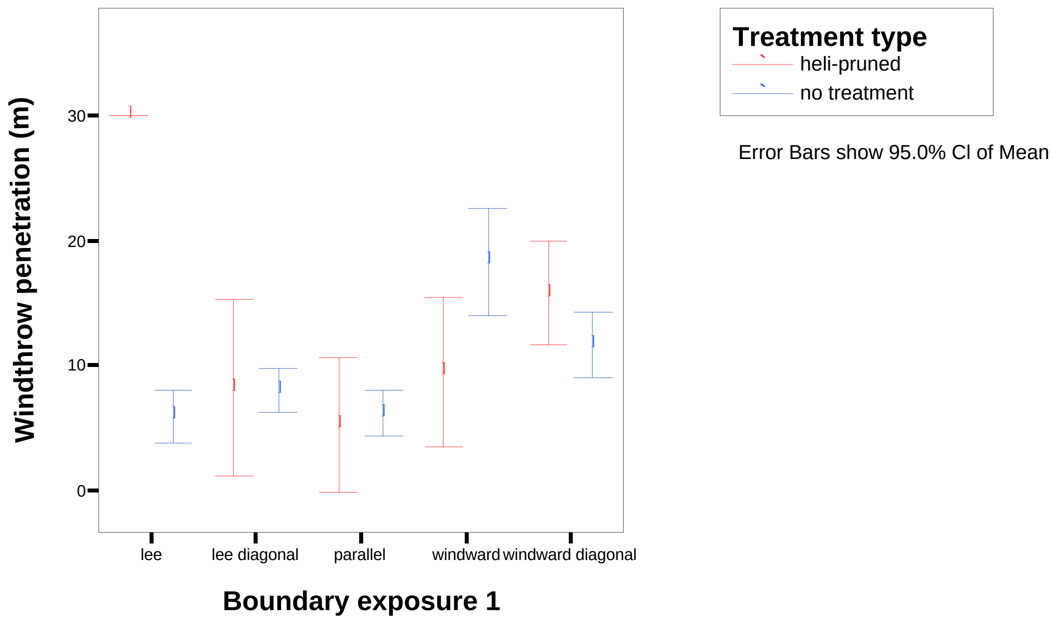
Average stand heights >30m. Cases weighted by length-based weighting factor.

Figure A5. Percent windthrow by treatment with variations in boundary geometry along external block edges.



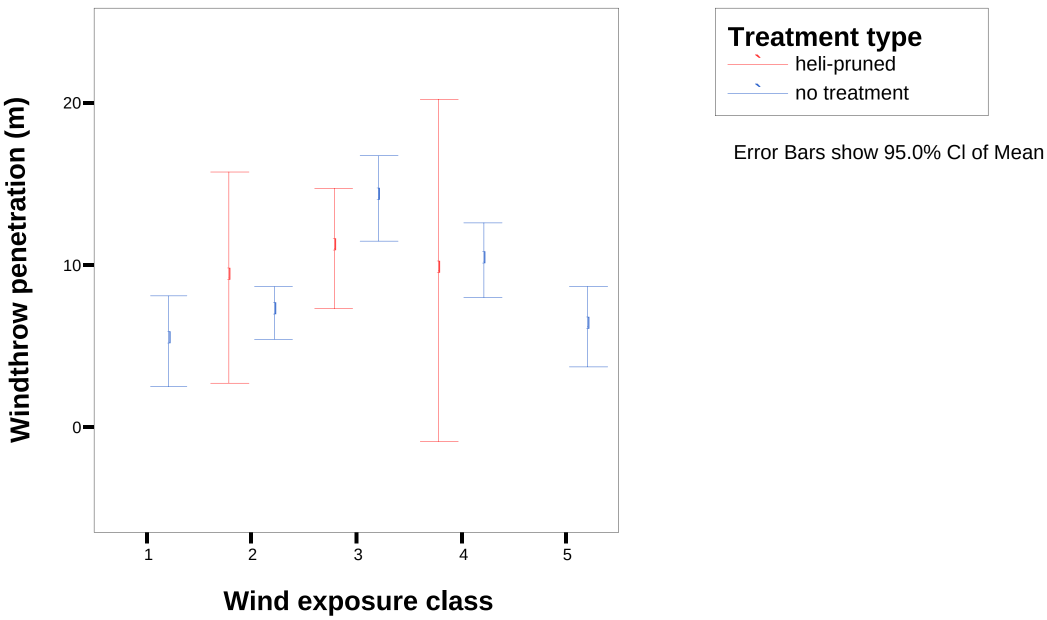
Average stand heights >30m. Cases weighted by length-based weighting factor.

Figure A5. Windthrow penetration by treatment – external block edges.



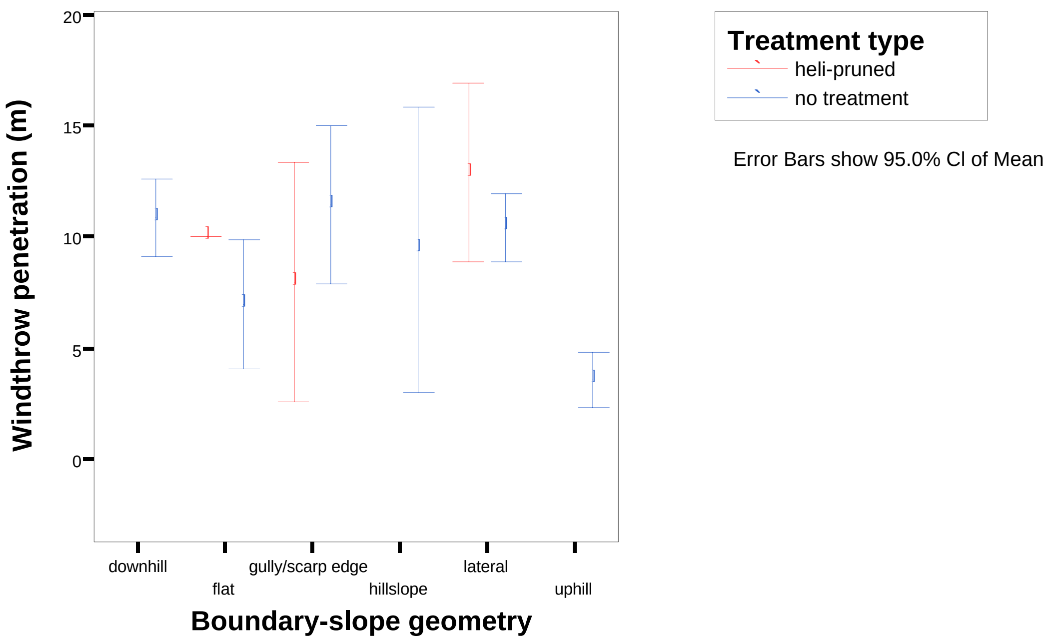
Average stand heights >30m. Cases weighted by length-based weighting factor.

Figure A6. Windthrow penetration by boundary exposure class – external edges.



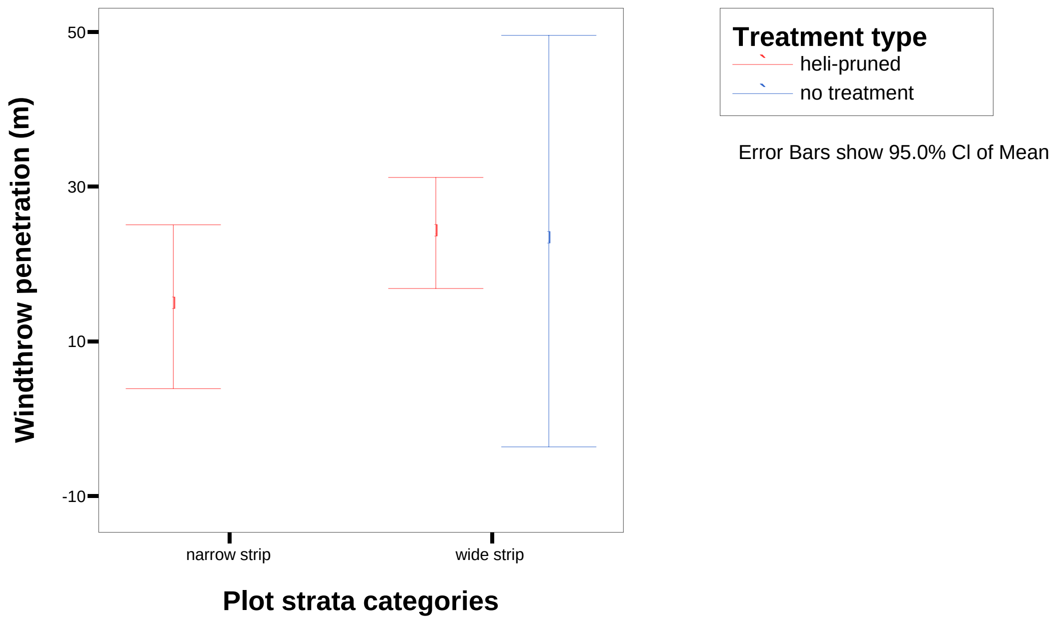
Average stand heights >30m. Cases weighted by length-based weighting factor.

Figure A7. Windthrow penetration by wind exposure class – external block edges.



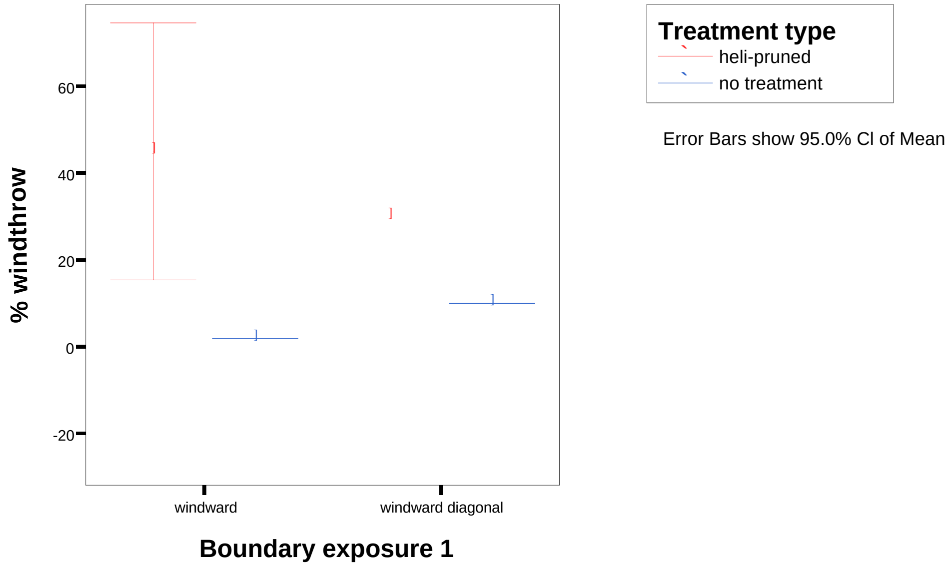
Average stand heights >30m. Cases weighted by length-based weighting factor.

Figure A7. Windthrow penetration by treatment with changes in boundary geometry – external block edges.



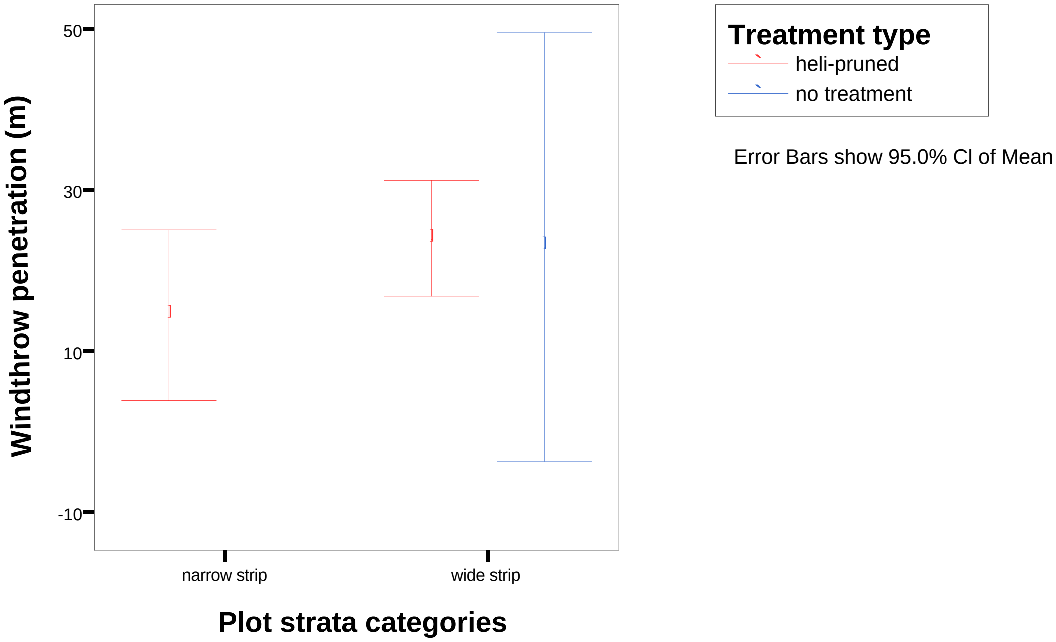
Average stand heights >30m. Cases weighted by length-based weighting factor.

Figure A8. **Comparison of percent windthrow along retained strips <50 meters wide and >50 meters wide.**



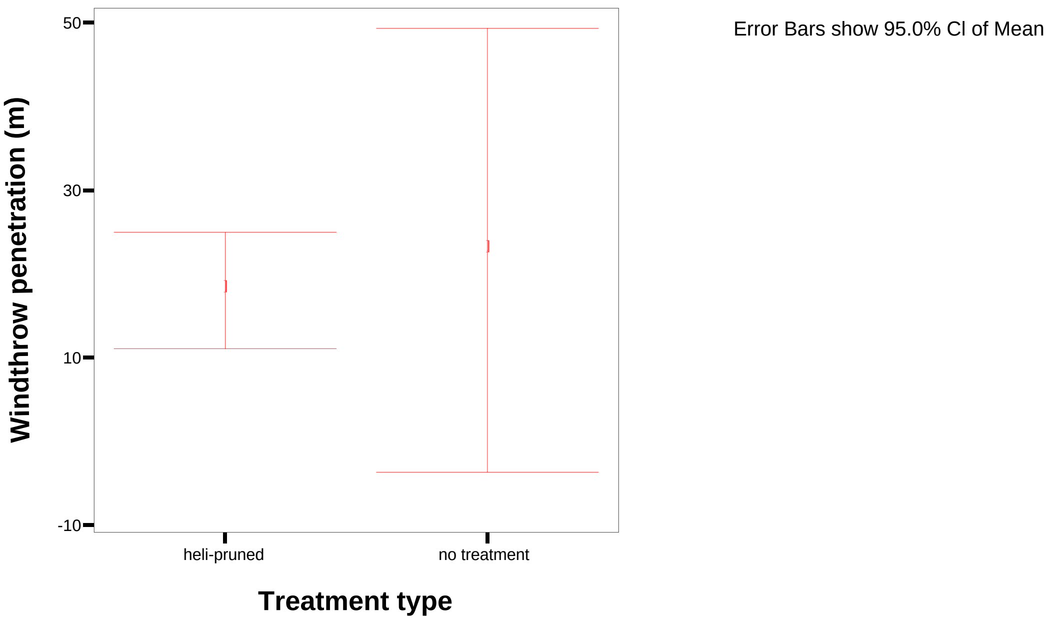
Average stand heights >30m, strips >50m wide, weighted by length-based weighting factor.

Figure A9. **Comparison of percent windthrow along retained strips >50 meters wide with windward and windward diagonal boundary exposures.**



Average stand heights >30m. Cases weighted by length-based weighting factor.

Figure A10. Comparison of windthrow penetration for retained strips <50 meters wide and >50 meters wide.



Average stand heights >30m. Cases weighted by length-based weighting factor.

Figure A11. Comparison of windthrow penetration along retained strips > 50 meters wide with windward and windward diagonal boundary exposures.

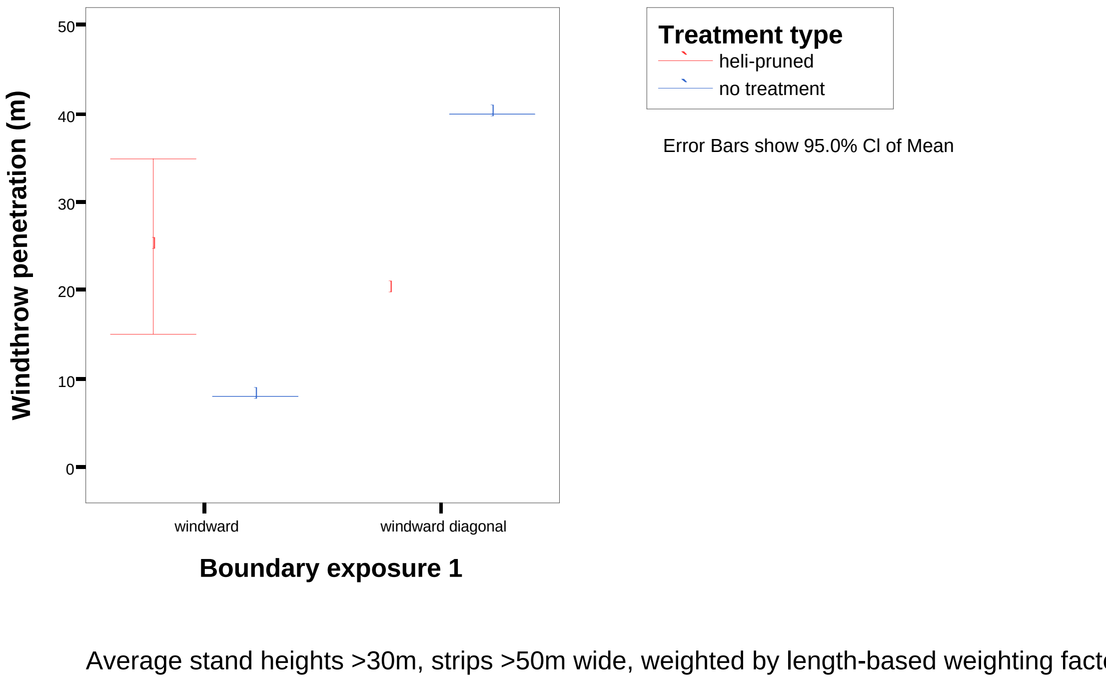
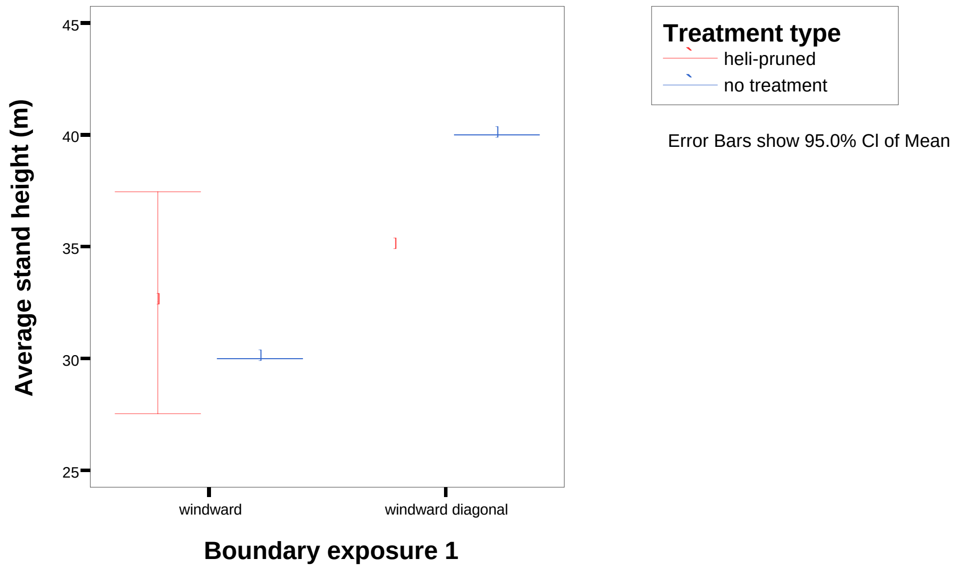
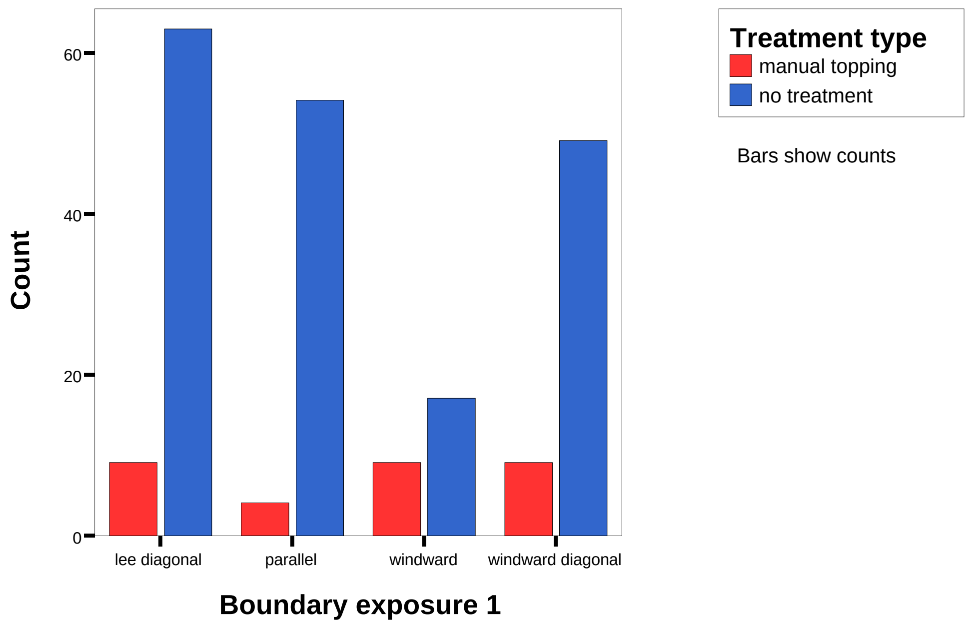


Figure A12. Comparison of windthrow penetration along retained strips >50 meters wide with windward and windward diagonal boundary exposures.



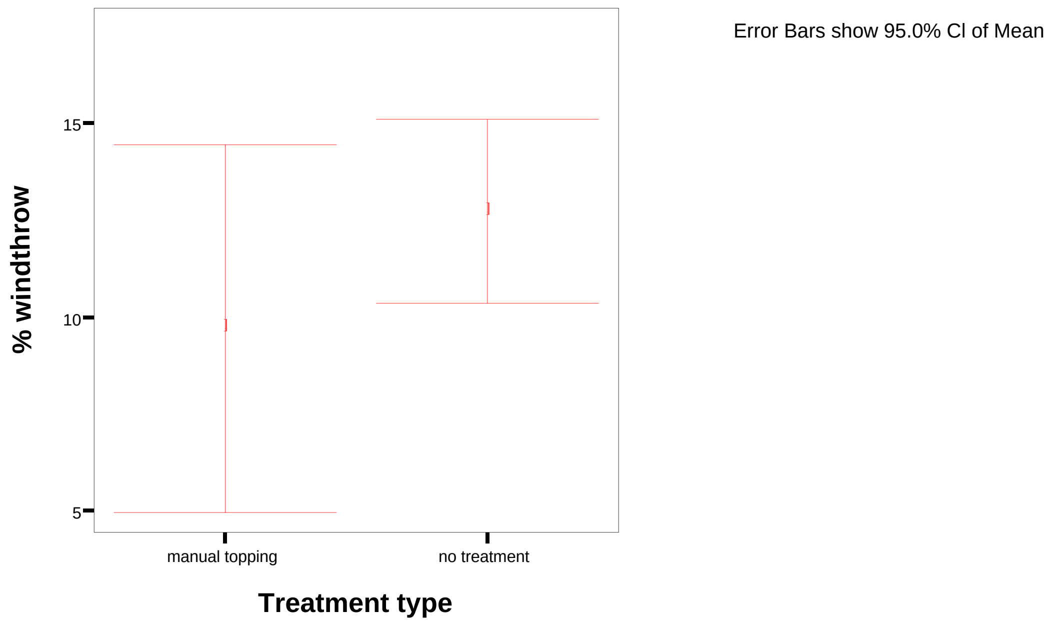
Average stand heights >30m, strips >50m wide, weighted by length-based weighting factor.

Figure A13. Mean stand height comparison for retained strips >50 meters wide.



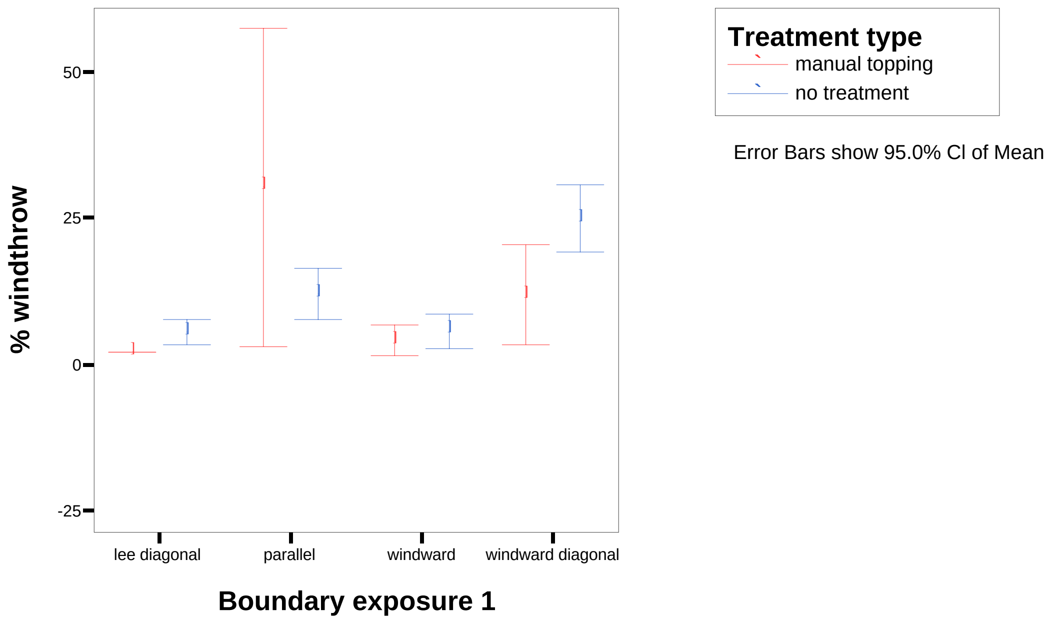
Average stand heights >30 m. Cases weighted by length-based weighting factor.

Figure A14. Distribution of plots by boundary exposure class for external block edges.



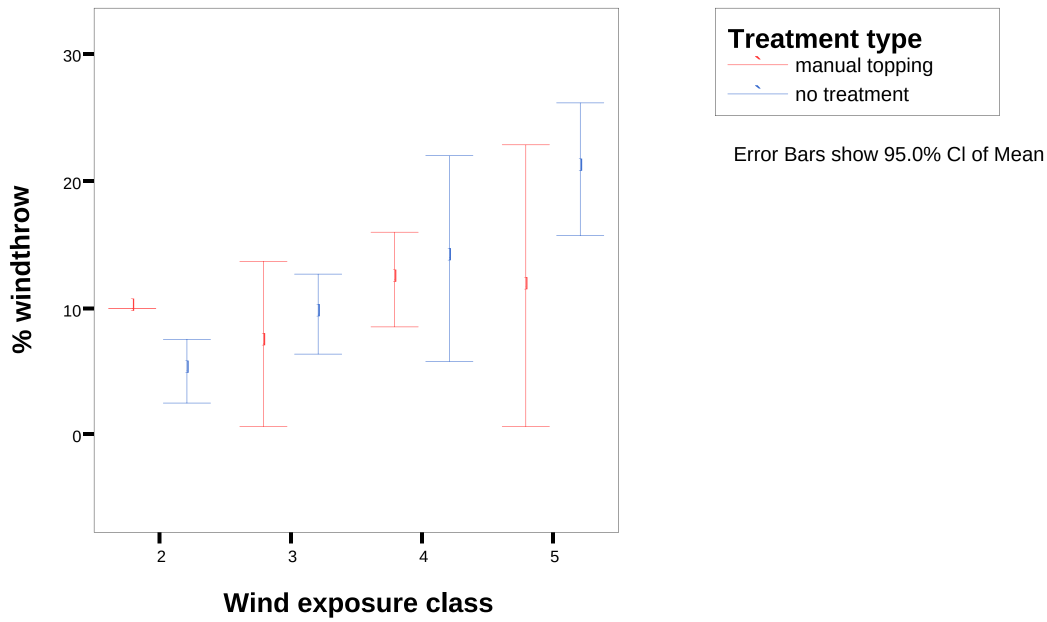
Average stand heights >30m. Cases weighted by length-based weighting factor.

Figure A15. Windthrow percentages for manually topped plots along external block edges.



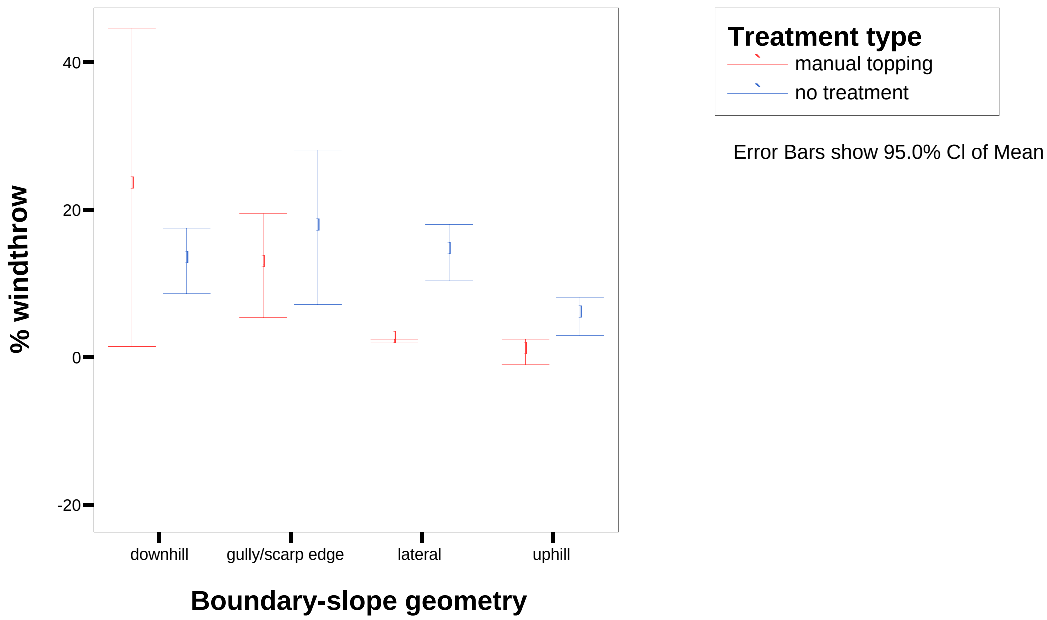
Average stand heights >30m. Cases weighted by length-based weighting factor.

Figure A16. Percent windthrow by treatment by boundary exposure classes along external block edges.



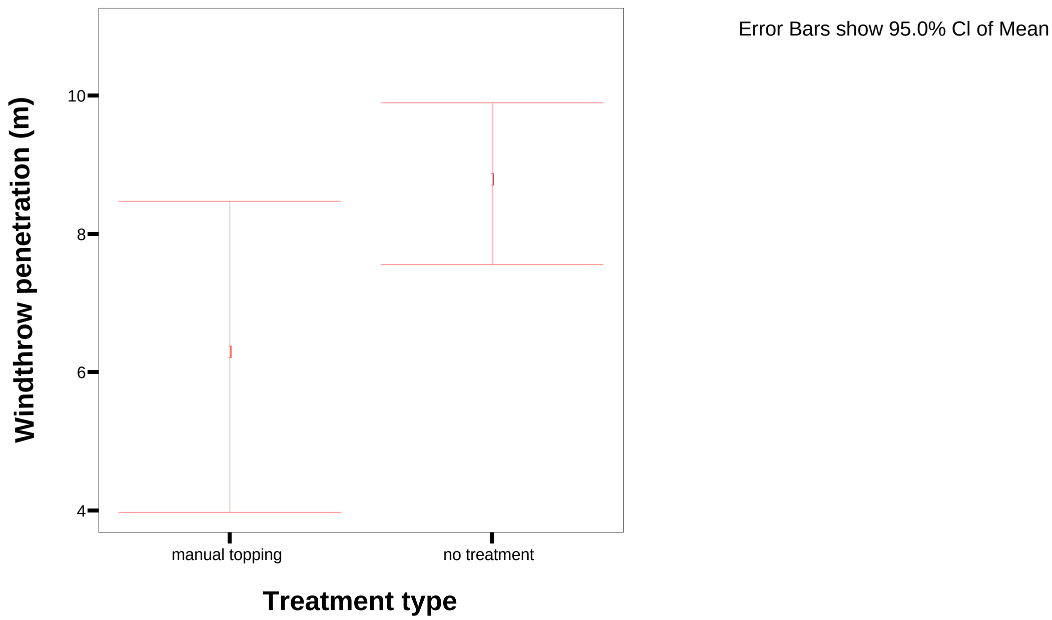
Average stand heights >30m. Cases weighted by length-based weighting factor.

Figure A17. Percent windthrow by treatment by wind exposure class along external block edges.



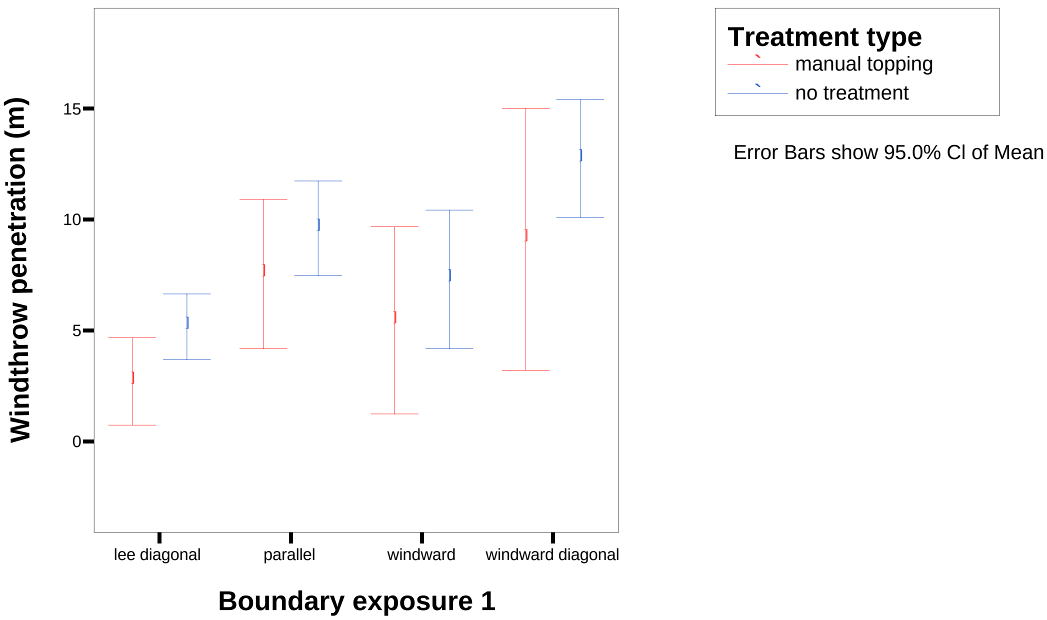
Average stand heights >30m. Cases weighted by length-based weighting factor.

Figure A18. Percent windthrow by treatment with variations in boundary-slope geometry along external block edges.



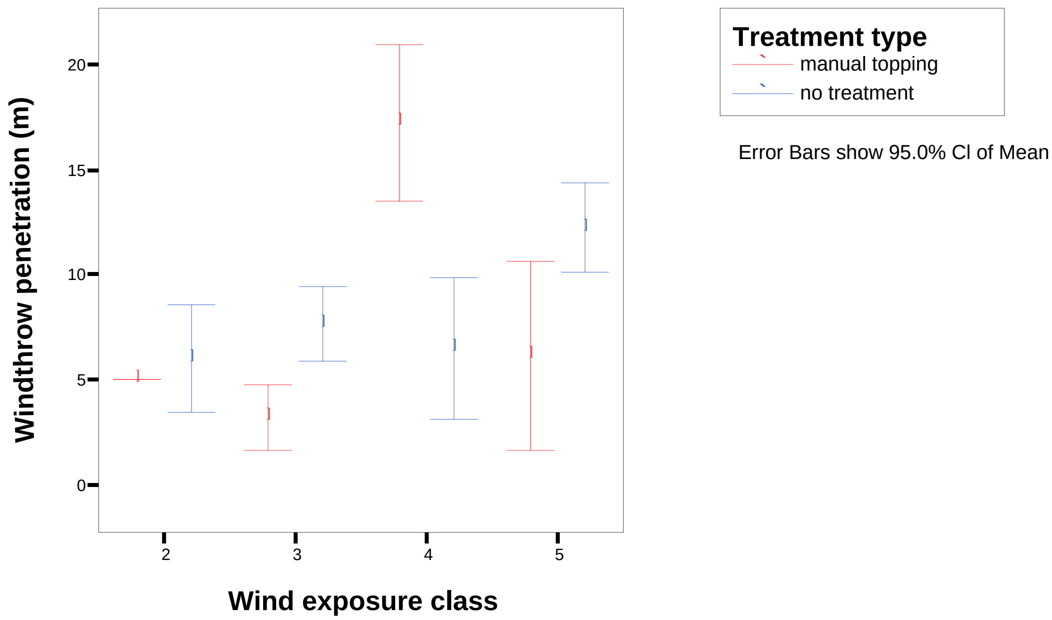
Average stand heights >30m. Cases weighted by length-based weighting factor.

Figure A19. Windthrow penetration by treatment along external block edges.



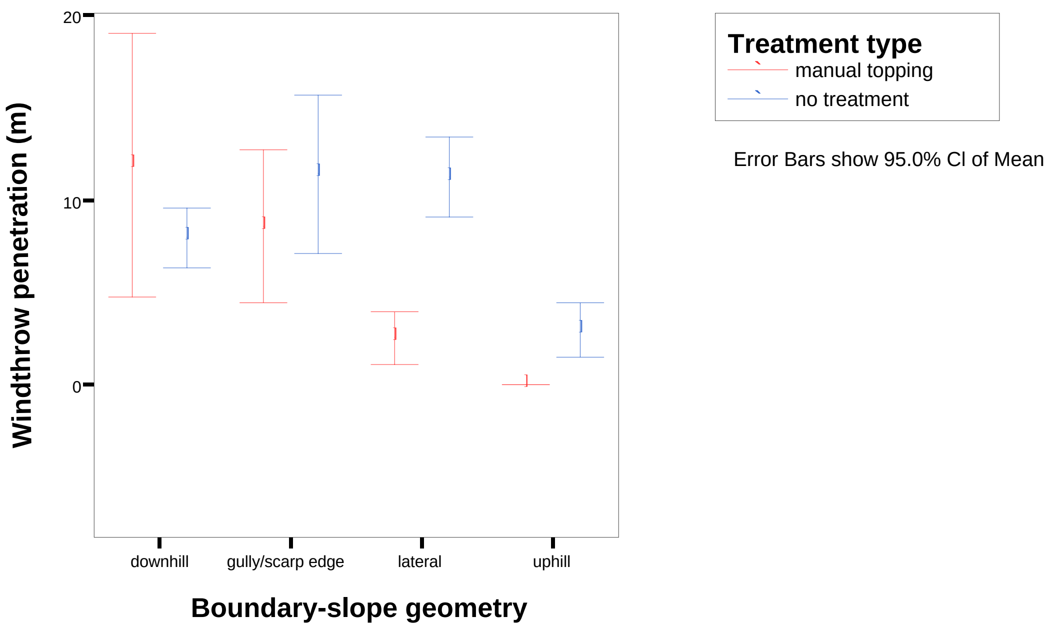
Average stand heights >30m. Cases weighted by length-based weighting factor.

Figure A20. Windthrow penetration by boundary exposure class - external edges.



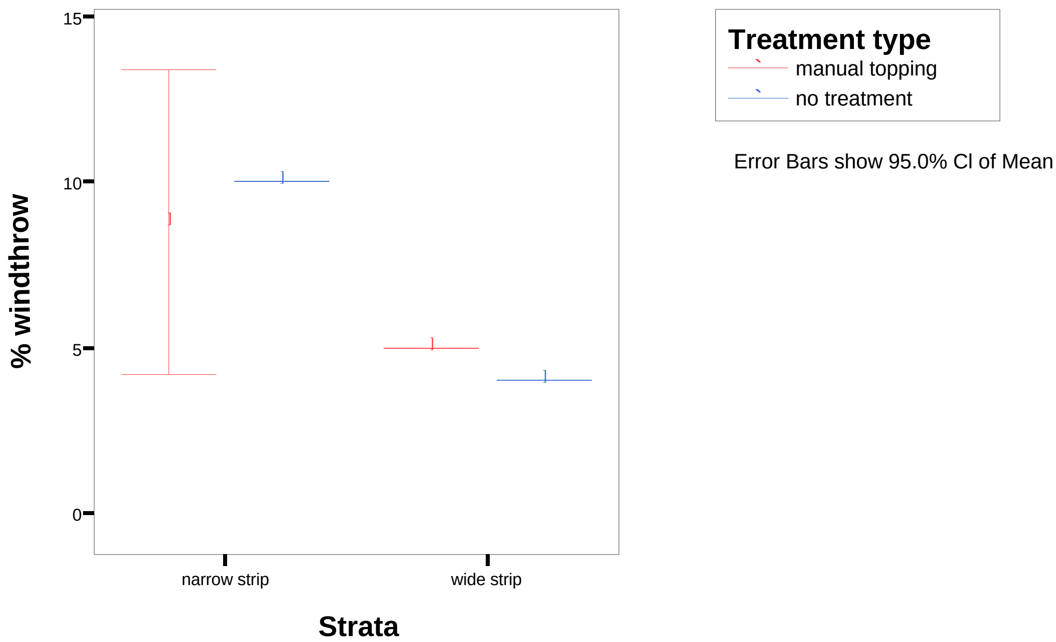
Average stand heights >30m. Cases weighted by length-based weighting factor.

Figure A21. Windthrow penetration by wind exposure class - external edges.



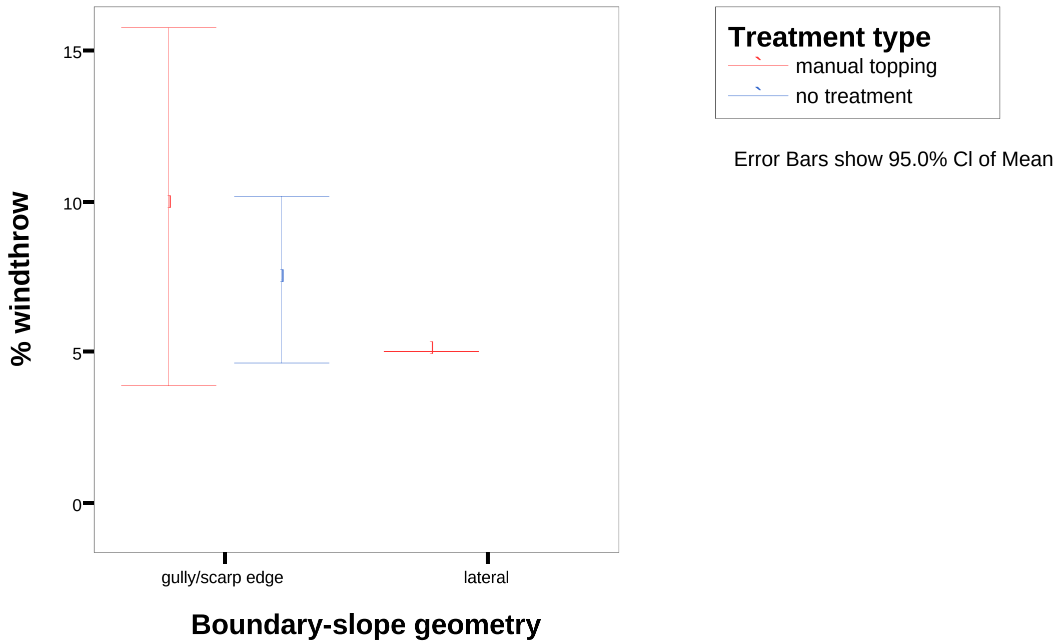
Average stand heights >30m. Cases weighted by length-based weighting factor.

Figure A22. Windthrow penetration with changes in boundary-slope geometry along external block edges.



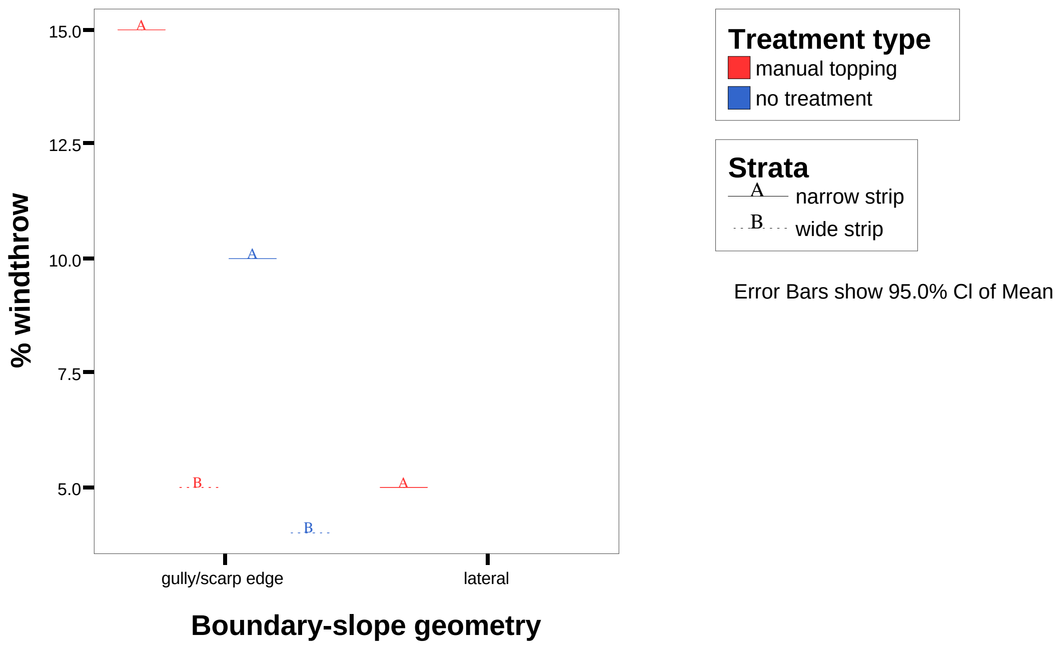
Average stand heights >30m. Cases weighted by length-based weighting factor.

Figure A23. Percent windthrow by treatment for narrow and wide retained strips.



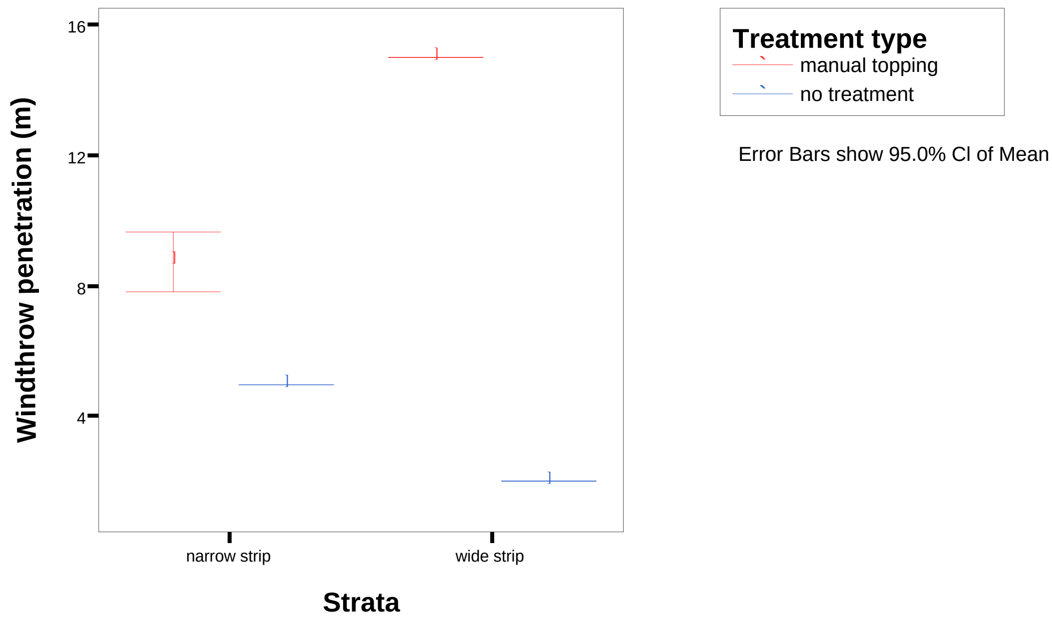
Average stand heights >30m. Cases weighted by length-based weighting factor.

Figure A24. Percent windthrow by treatment for narrow and wide retained strips with changes in boundary-slope geometry.



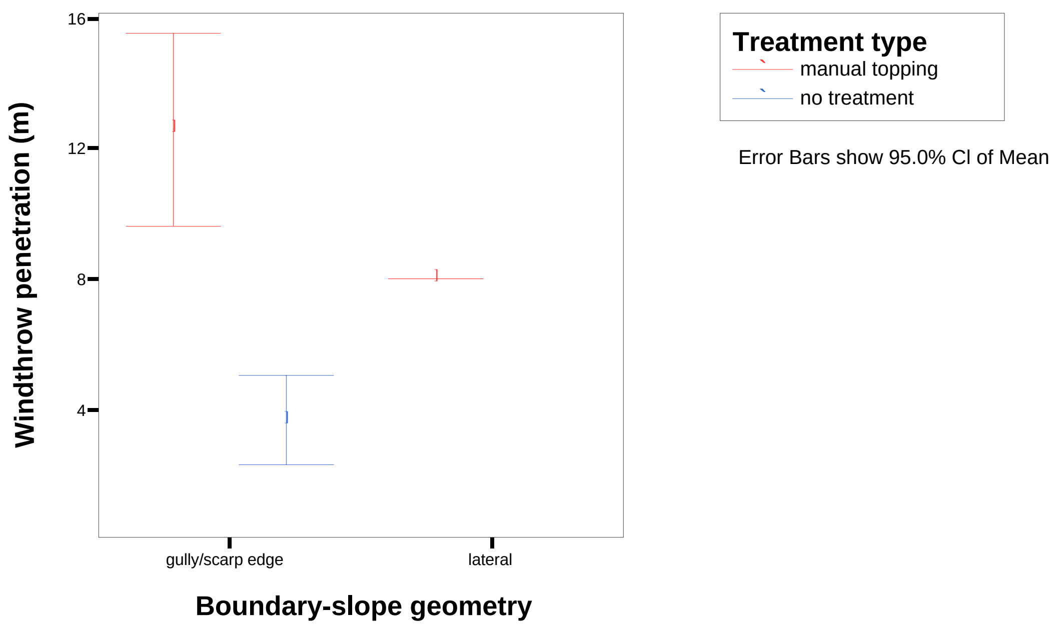
Average stand heights >30m. Cases weighted by length-based weighting factor.

Figure A25. Percent windthrow by treatment for both narrow and wide strips and changes in boundary-slope geometry.



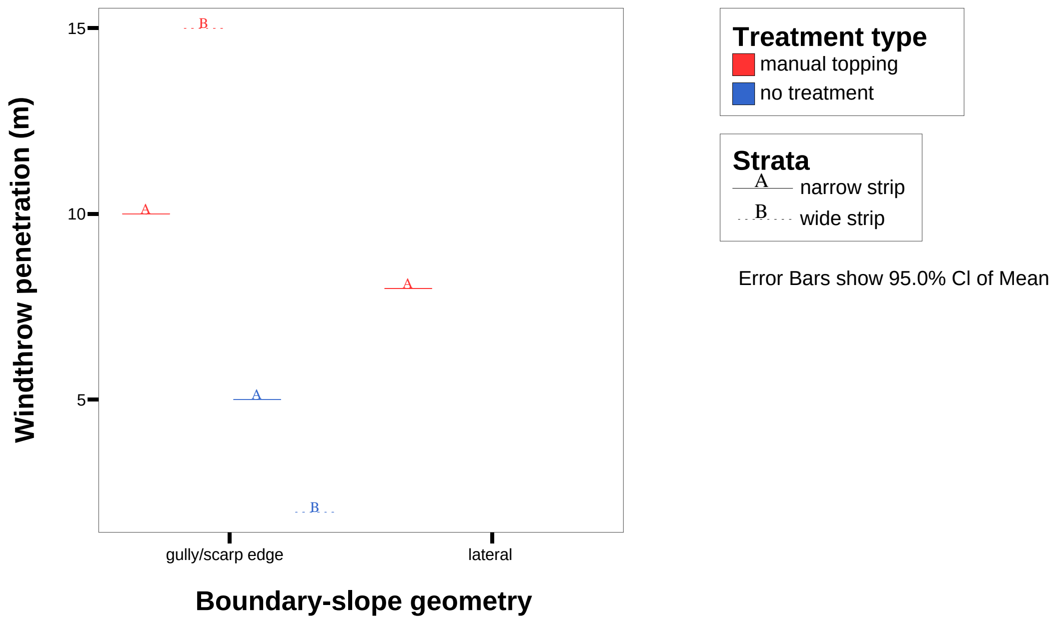
Average stand heights >30m. Cases weighted by length-based weighting factor.

Figure A26. Windthrow penetration by treatment for narrow and wide retained strips.



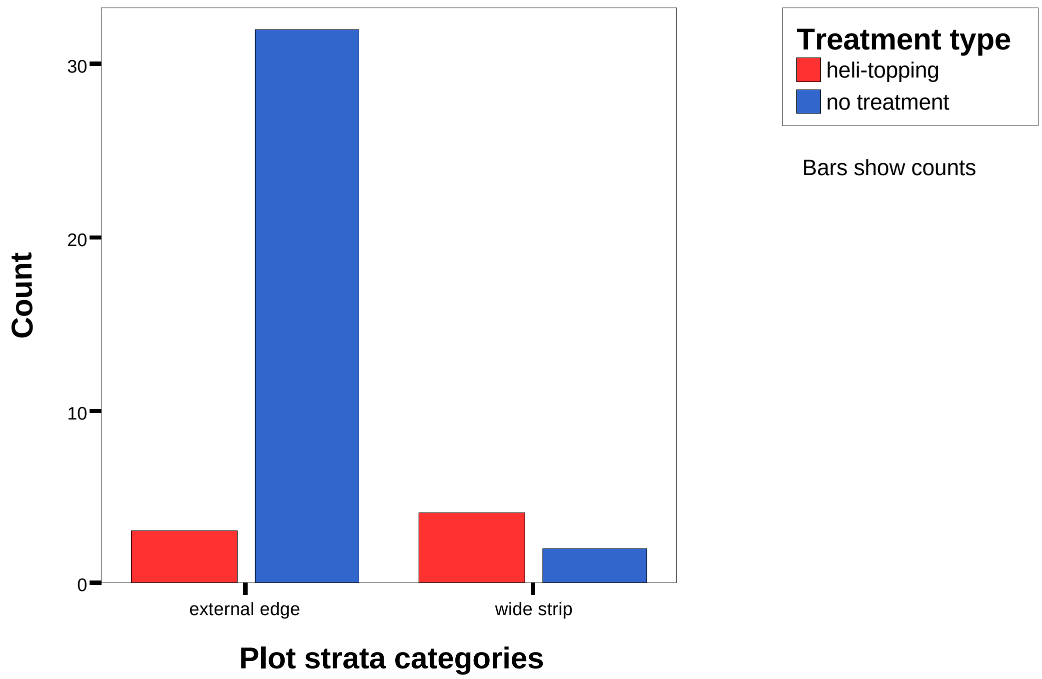
Average stand heights >30m. Cases weighted by length-based weighting factor.

Figure A27. Windthrow penetration by treatment for narrow and wide retained strips by boundary-slope geometry categories.



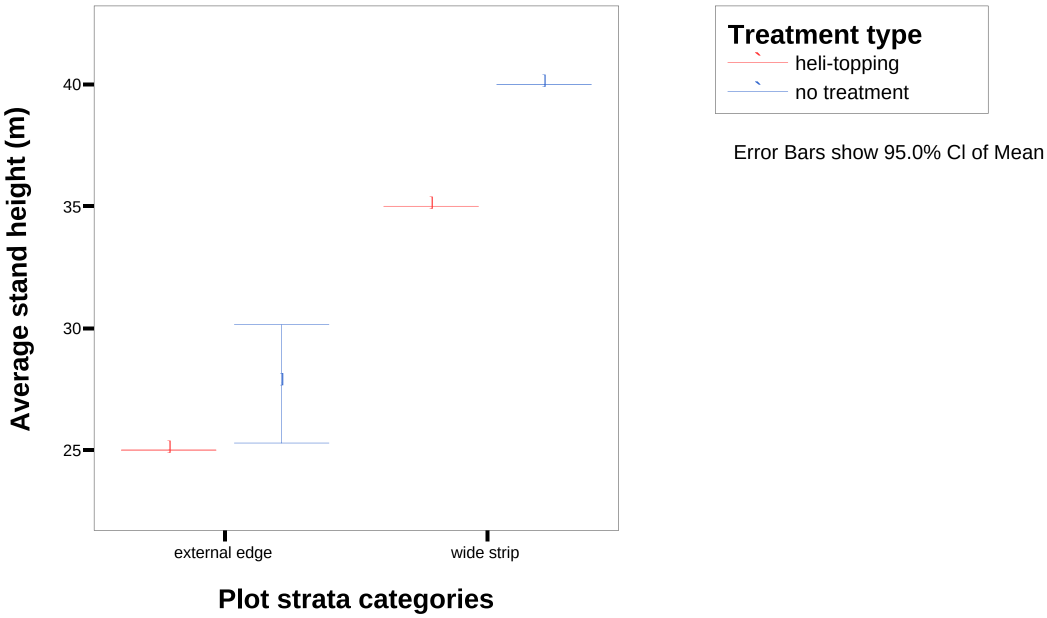
Average stand heights >30m. Cases weighted by length-based weighting factor.

Figure A28. Windthrow penetration by both treatment for narrow and wide retained strips and by boundary-slope geometry categories.



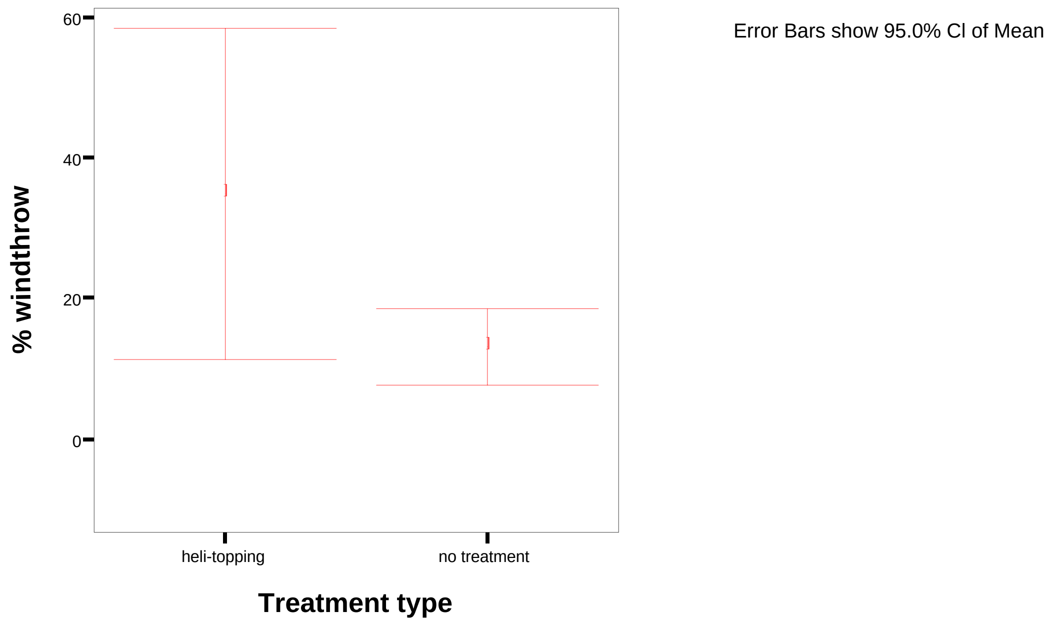
Cases weighted by length-based weighting factor.

Figure A29. Heli-topping comparison for external edges and wide strips.



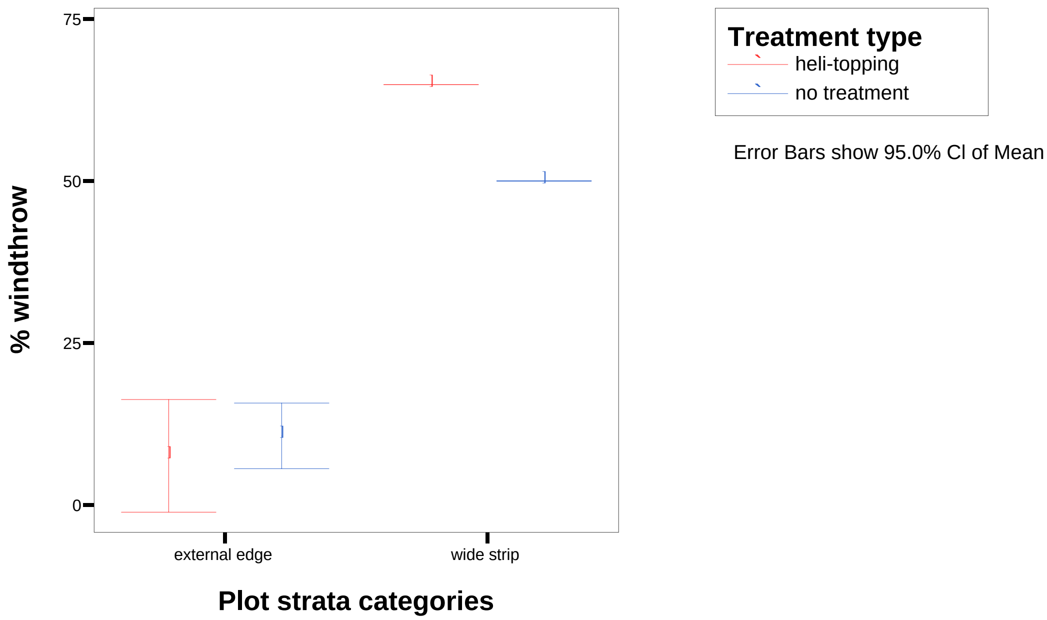
Cases weighted by length-based weighting factor.

Figure A30. Heli-topping estimated average stand heights comparison for external edges and wide strips.



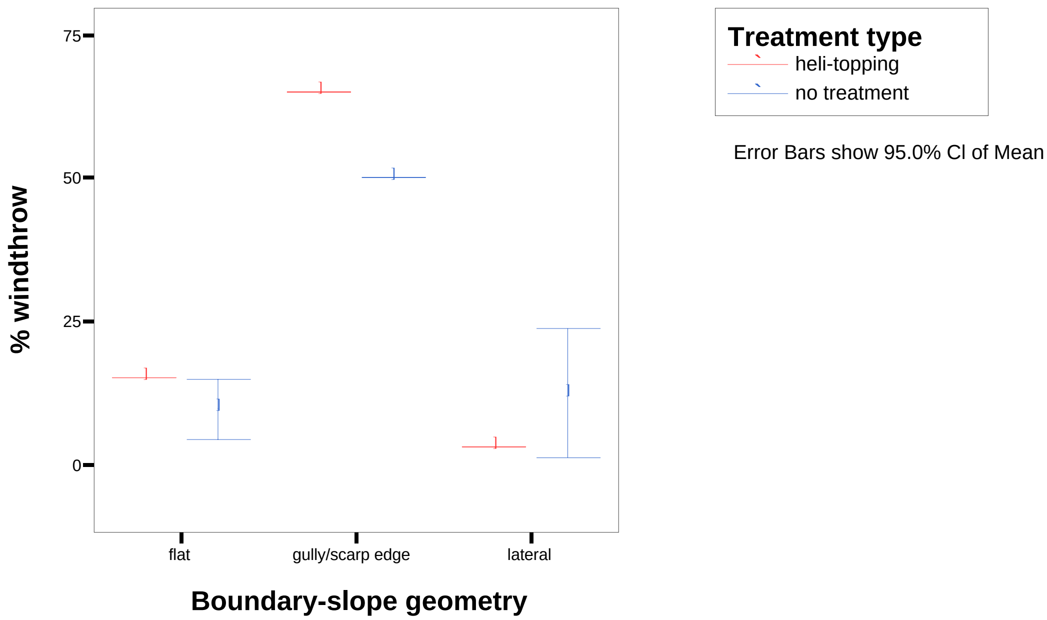
Cases weighted by length-based weighting factor.

Figure A31. Heli-topping percent windthrow general comparison for external edges and wide strips.



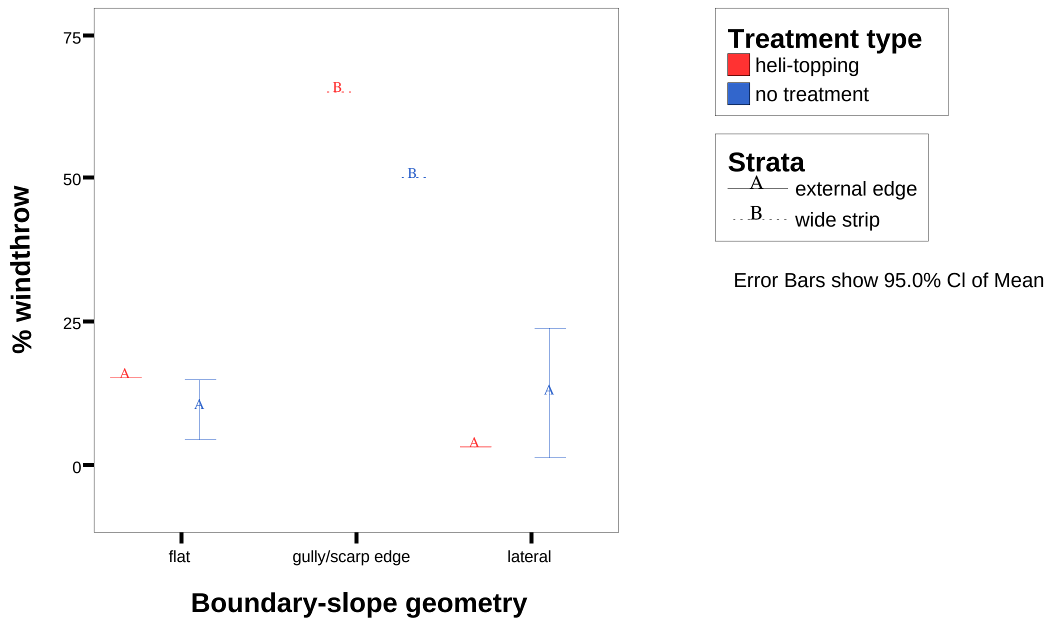
Cases weighted by length-based weighting factor.

Figure A32. Heli-topping percent windthrow comparison for external edges and wide strips.



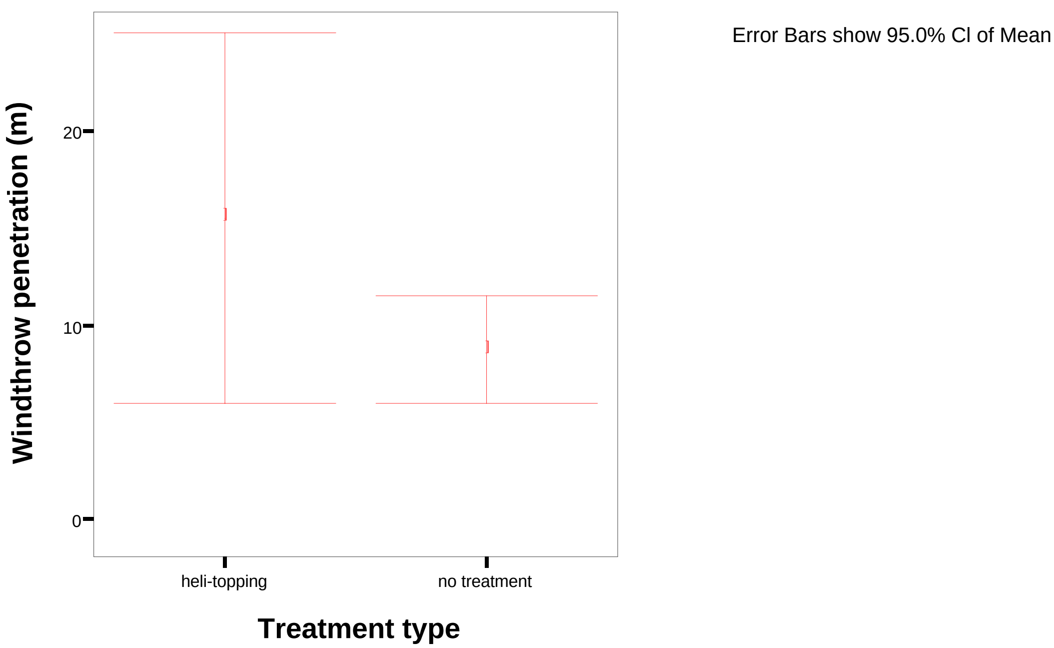
Cases weighted by length-based weighting factor.

Figure A33. Heli-topping percent windthrow comparison for boundary-slope geometry for external edges and wide strips.



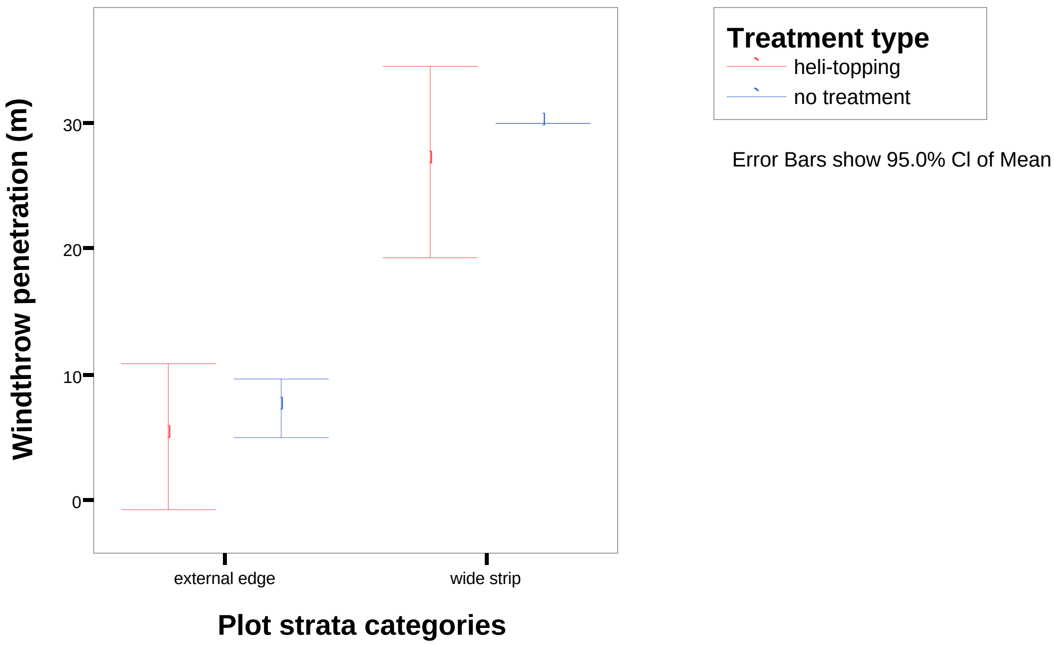
Cases weighted by length-based weighting factor.

Figure A34. Heli-topping percent windthrow comparison for boundary-slope geometry for external edges and wide strips.



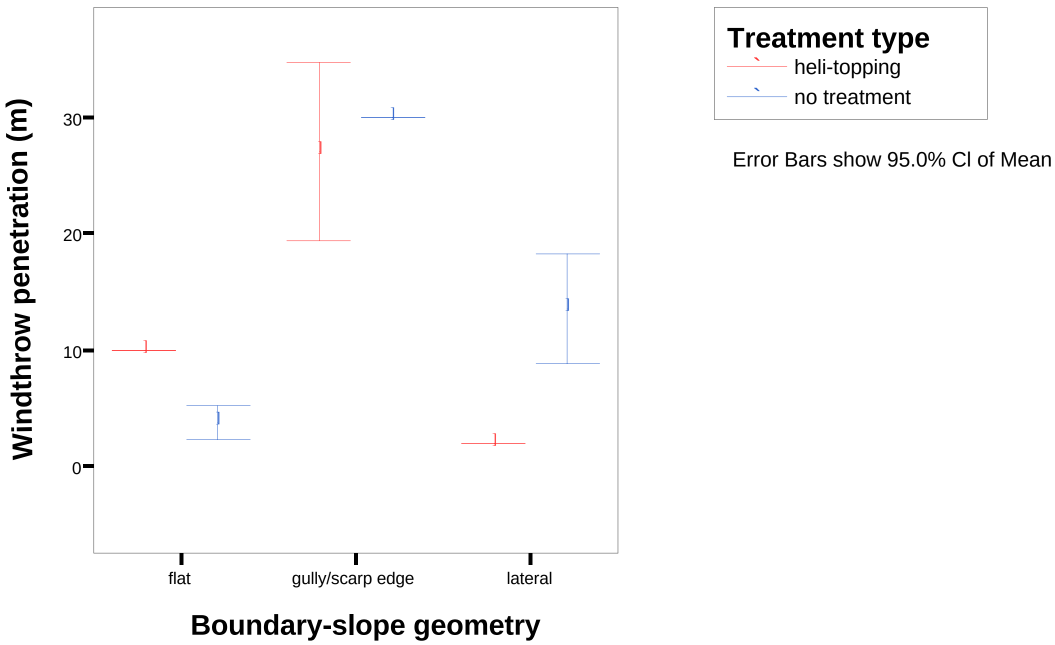
Cases weighted by length-based weighting factor.

Figure A35. Heli-topping windthrow penetration general comparison external edges and wide strips.



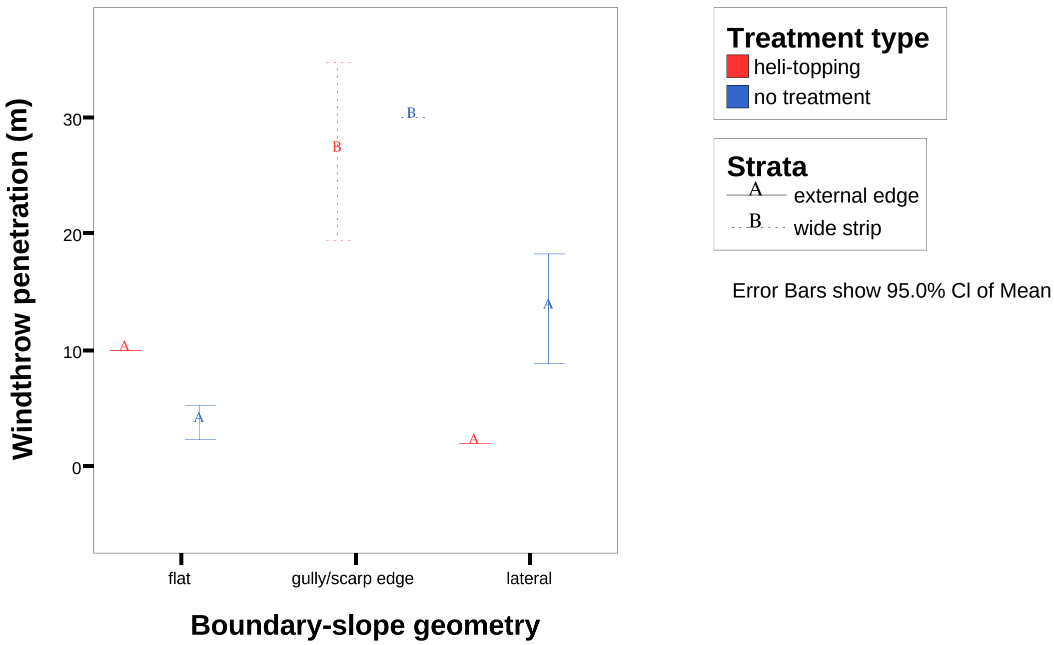
Cases weighted by length-based weighting factor.

Figure A36. Heli-topping windthrow penetration comparison external edges and wide strips.



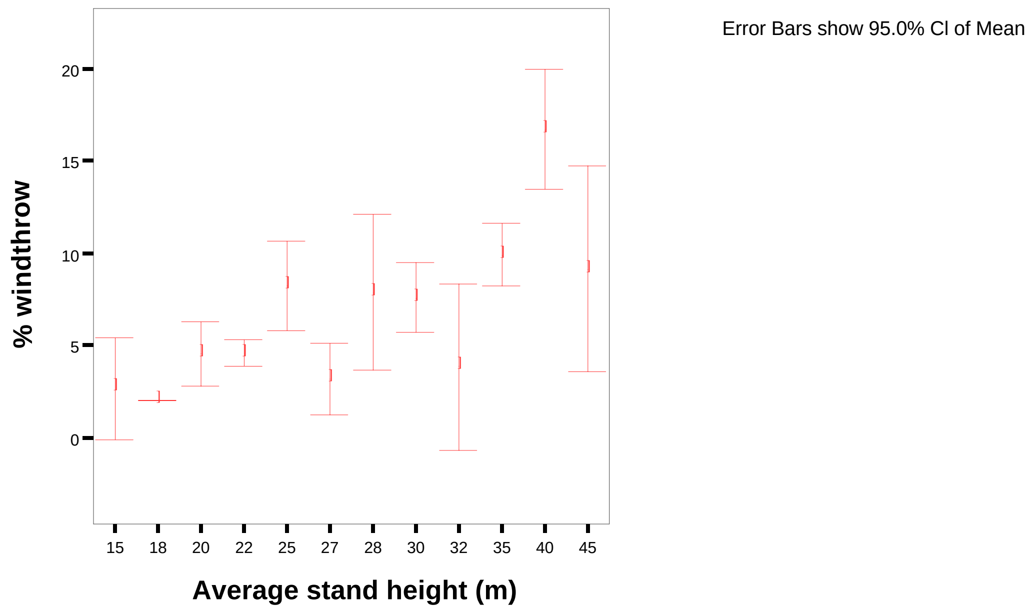
Cases weighted by length-based weighting factor.

Figure A37. Heli-topping windthrow penetration comparison of boundary-slope geometry for external edges and wide strips.



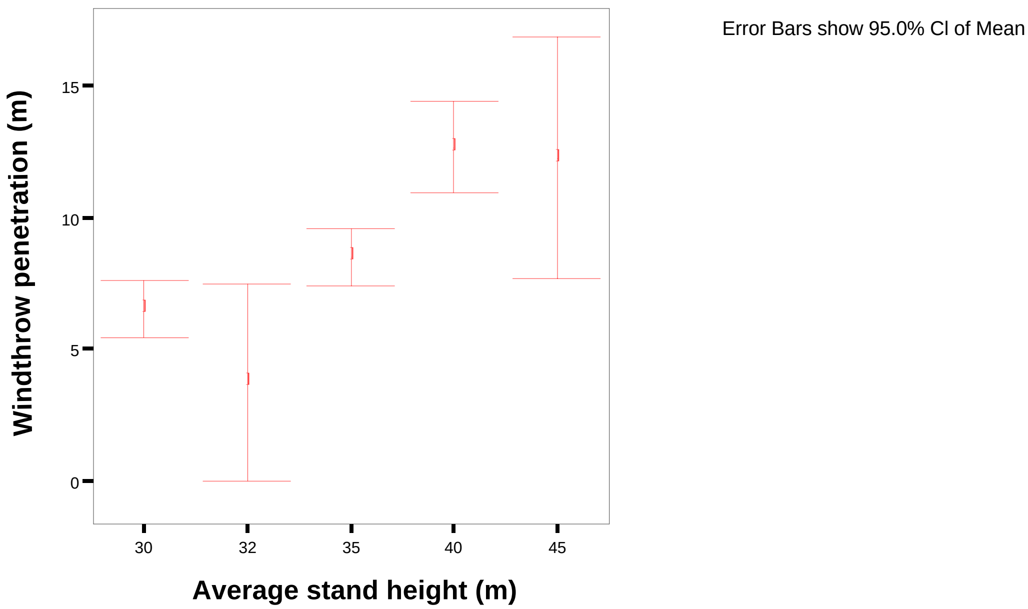
Cases weighted by length-based weighting factor.

Figure A38. Heli-topping windthrow penetration comparison of boundary-slope geometry for external edges and wide strips.



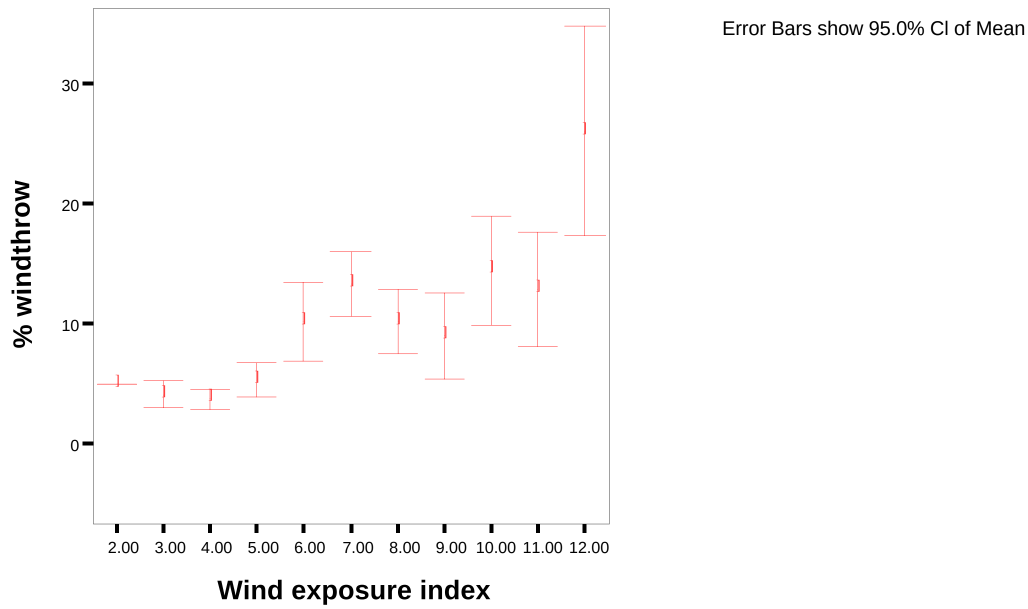
Untreated plots on external block edges, weighted by length-based weighting factor.

Figure U1. Comparison of average stand height to percent windthrow.



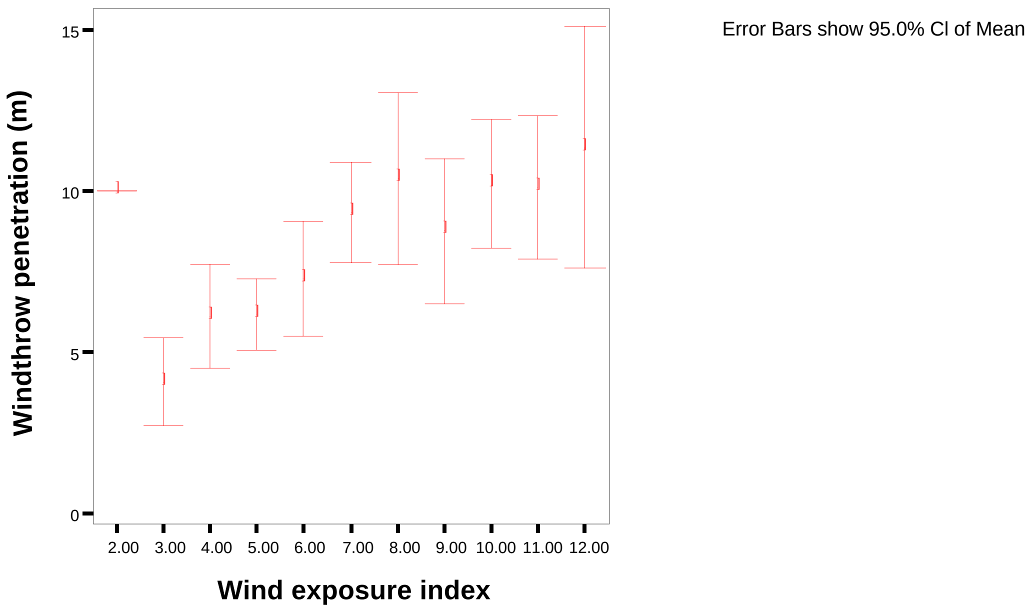
Untreated plots on external block edges, weighted by length-based weighting factor.

Figure U2. Comparison of average stand height to windthrow penetration.



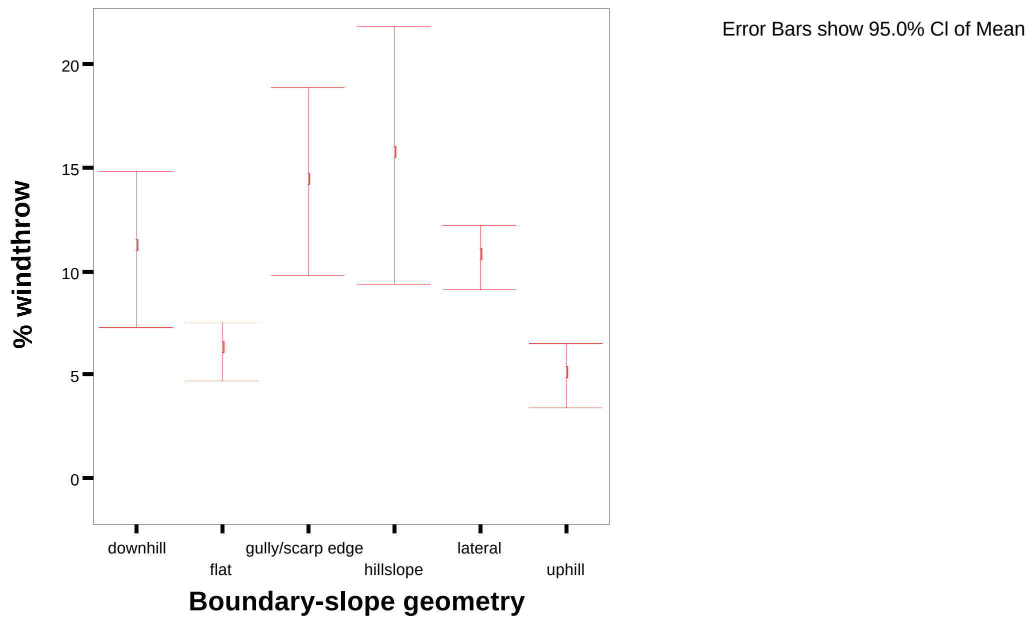
Untreated plots on external block edges, weighted by length-based weighting factor.

Figure U3. Comparison of wind exposure index to percent windthrow.



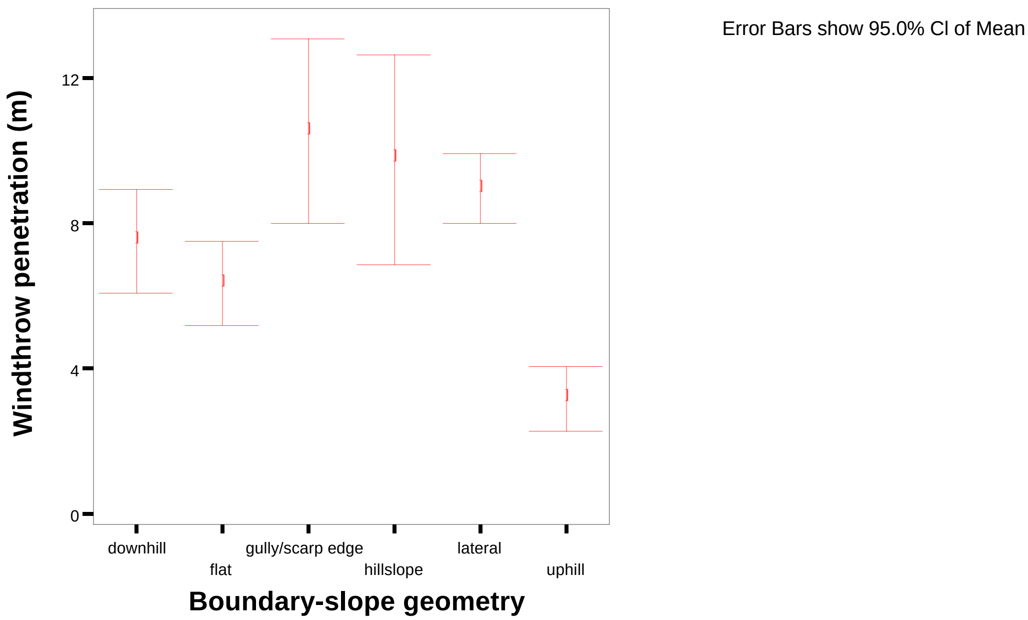
Untreated plots on external block edges, weighted by length-based weighting factor.

Figure U4. Comparison of wind exposure index to windthrow penetration.



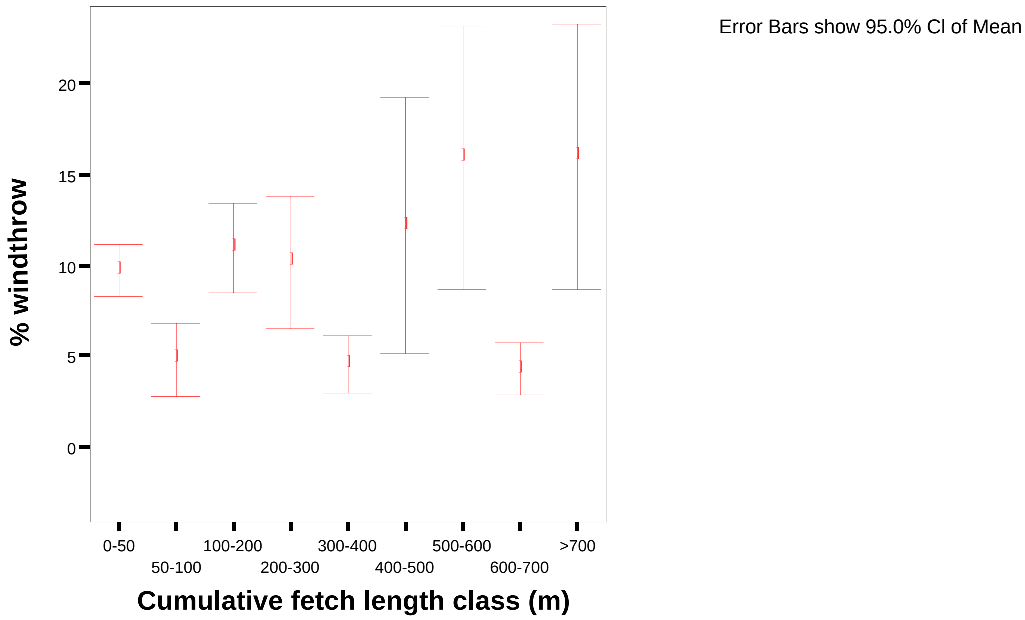
Untreated plots on external block edges, weighted by length-based weighting factor.

Figure U5. Comparison of boundary-slope geometry classes to percent windthrow.



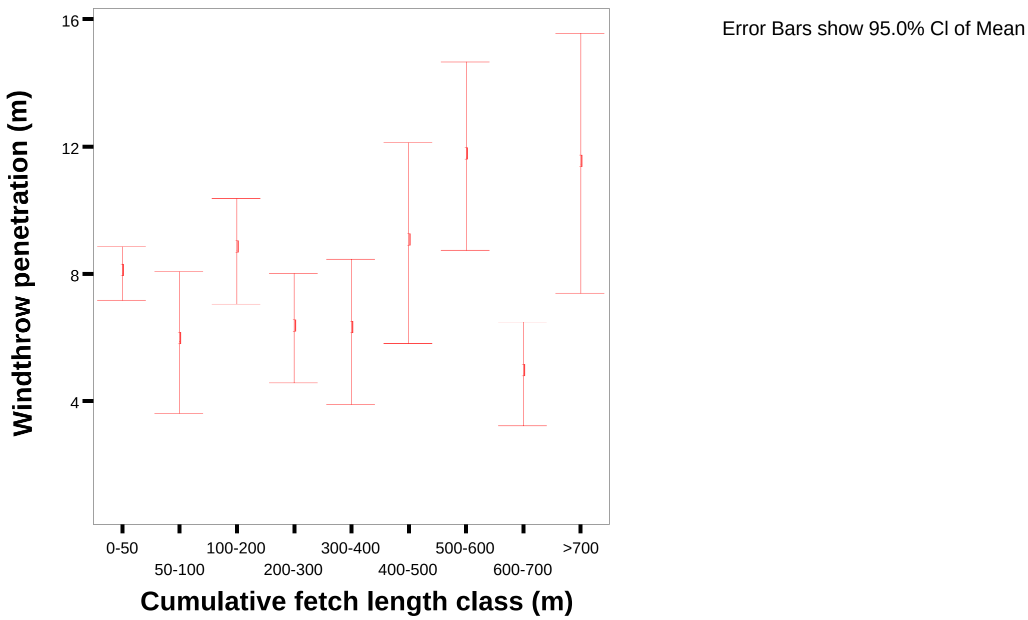
Untreated plots on external block edges, weighted by length-based weighting factor.

Figure U6. Comparison of boundary-slope geometry to windthrow penetration.



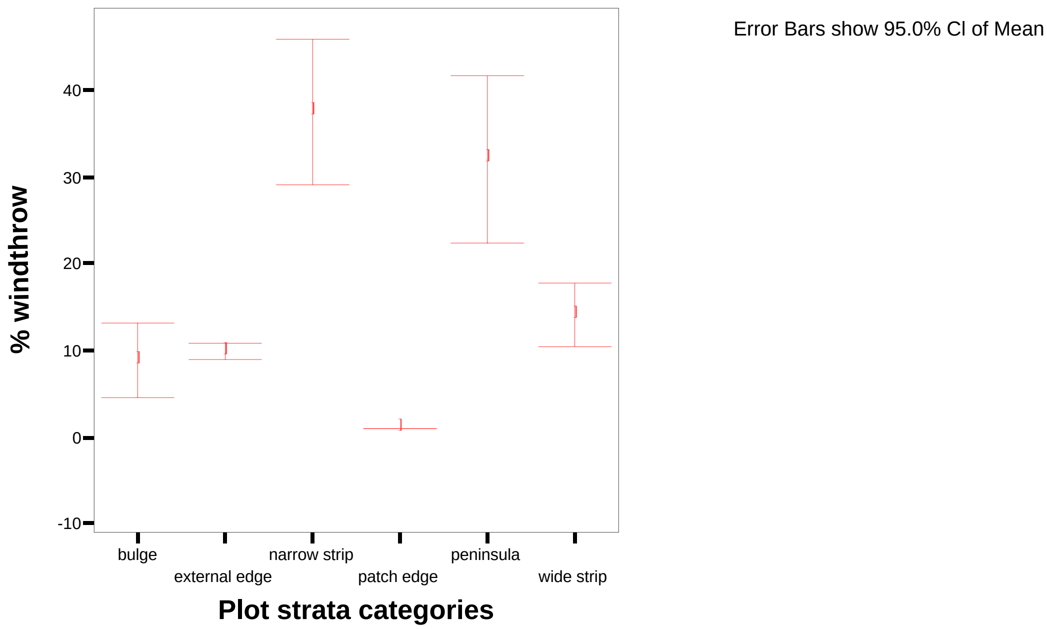
Untreated plots on external block edges, weighted by length-based weighting factor.

Figure U7. Comparison of cumulative fetch distance class to percent windthrow.



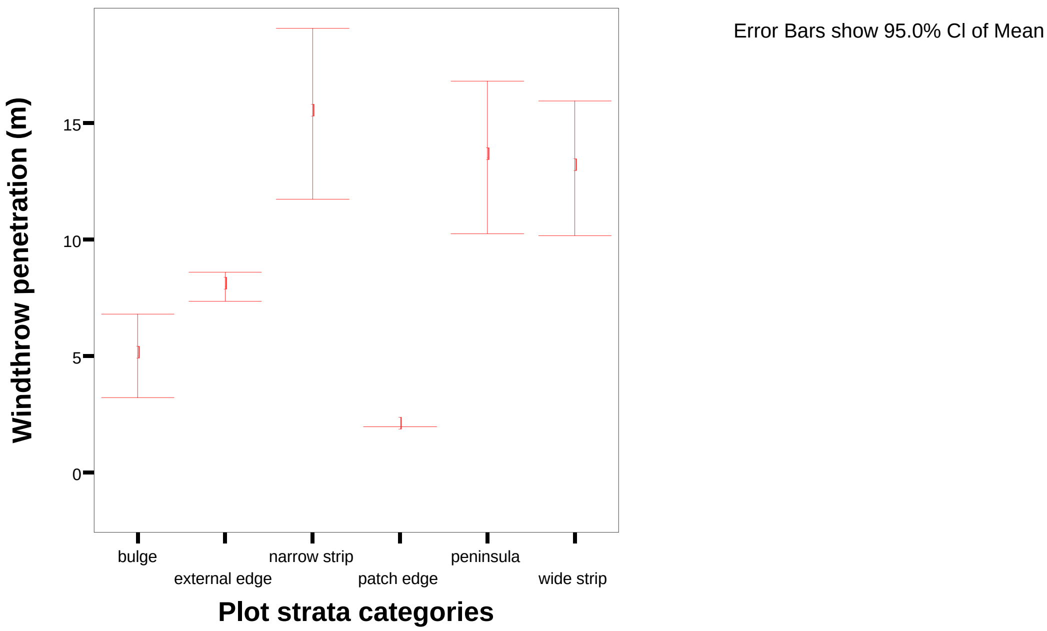
Untreated plots on external block edges, weighted by length-based weighting factor.

Figure U8. Comparison of cumulative fetch distance to windthrow penetration.



Untreated plots all strata, weighted by length-based weighting factor.

Figure U9. Comparison of plot strata categories to percent windthrow.



Untreated plots all strata, weighted by length-based weighting factor.

Figure U10. Comparison of plot strata categories to windthrow penetration.

Appendix III
Data Coding Documentation

Note: The data coding conventions included in this appendix are the same as are used for the variable retention windthrow monitoring project; however, the majority of these attributes were not recorded for the edge treatment pilot study.

Windthrow Assessment Codes and Coding Procedure[3]:

Enter a unique plot number and the block number, division, watershed, silviculture system and date falling was completed for the block across the top of the form.

Falling Corner Range

- Enter the falling corners that define the two ends of the plot. Where a plot boundary falls between two falling corners list the distance in metres past the last falling corner (e.g. FC 17+50)

*Terrain**

- O – organic M – moraine,
- C – colluvial, R – bedrock,
- F – fluvial, L – lacustrine,
- W - marine

Slope position

- C – crest (i.e., a ridge crest)
- U – upper
- M – mid
- L – lower
- VF – valley flat

Slope morphology

- P – planar or uniform – any slope angle
- U – undulating, - generally level to gently sloping areas
- I – irregular – generally limited to surface irregularities €1- 2 metres
- B – benchy
- H – hummocky – surface irregularities generally of ⁄5 metres
- D – dissected (more than one gully across the slope)
- G – single gully generally ⁄3 metres deep
- E – stream escarpment generally ⁄5 metres high
- S - depressional

*Soils**

- P – podzols – brown to orange colored, well drained mineral soils
- GP – gleyed podzols – imperfectly drained soils, evidence of gleying (mottles) in the mineral soil

[3] Combinations of some of these variable codes are possible.

- G – gleysols – grey colored soils often with a black organic upper horizon, poorly drained soils
- HG – Humic gleysols – gleysols with a thick upper humus (humic) layer above the mineral soil
- H – humisols (organic soils – boggy areas)
- F – folisols (thick humus over bedrock)

Soil Drainage Class

- R – rapidly drained (colluvial veneers and/or bedrock)
- W – well drained (podzols in relatively deep materials and moderate to steep slopes)
- M – moderately well drained (podzols and gleyed podzols in deep materials on receiving sites)
- I – imperfectly drained (gleyed podzols)
- P – poorly drained (gleysols)
- VP – very poorly drained (organic soils – bogs)

Slope aspect

- The azimuth bearing perpendicular to and away from the slope.

Rooting depth

- Estimate average tree rooting depth to the nearest 10 cm increment for the leave area (plot).

Stand structure

- MS – dominantly multi-storied
- U – moderately uniform

Stand height

- Estimate average height of stand in the plot to the nearest metre (metres)

Stand origin

- U – unknown
- H – harvest (i.e. second growth timber)
- W – windthrow
- F – windfire
- I – insect

Tree species 1, 2, 3 and % for each species

- As on forest cover map or best estimate if forest cover map is not specific in order of dominance, with percent (%) as an integer to the nearest 10 percent (e.g., 3=30%)

Age class

- An integer (1, 2, 3 etc.) as on the forest cover map.

Density

- 1- dense
- 2 – moderate
- 3 - open

Windthrow (WT) %

- Estimate amount of windthrow as percentage of trees in stand that are⁄15 cm DBH within the first 25 metres into the stand edge or group or strip. Do not include saplings and regeneration in these estimates.

WT Spatial pattern – pattern of windthrow along/within boundary or leave area:

- U – uniform (well dispersed and continuous)
- I – irregular (more or less continuous but non-uniform pattern)
- G – small discrete groups of 1-5 trees
- P – patches (small discrete patches of windthrow, 1-2 tree lengths across, e.g., 10-20 trees)
- S – sections (> 5 tree lengths)

WT penetration

- Visually estimate the distance (in metres) that upturned roots (not tops) of windthrown trees are found into the leave area, stand edge, patch or group.

WT Orientation 1 and 2 and 3

- Estimate the average direction of the primary and secondary and tertiary orientations of windthrow in the plot. The direction of orientation is the direction parallel to the stem taken from the roots towards the top of the tree. In some cases there will only be one orientation.

% Stembreak/ %Leaning

- Estimate the percentage of trees in the plot that have broken stems and the percentage of trees that are leaning strongly (i.e., at an angle of⁄30 degrees away from the vertical) as a result of wind storms.

*WT treatment Rx**

- F – feathered edge (can only occur in a RMZ), FS – a feathered edge where only saplings are left.
- P – pruning
- T – topping
- N – none known or observed,
- X – thinned uniform– uniform tree removal throughout strip, all stem sizes retained (RMZ).
- Y – thinned small retained – generally only smaller merchantable trees retained (RMZ).
- PT – pruned and topped
- FP – feathered and topped
- FPT – feathered pruned and topped

Timing of treatment

- B – before harvest
- C – concurrent with harvest
- BW – before first winter
- AFW – after first winter
- ASW – after second winter

Slope angle in plot

- Record the average slope across the leave area except where the leave consists of gentle or moderate slopes adjacent to or above a gully or stream escarpment. In the latter case record in this field the average slope angle on the hillslope area adjacent to the gully or escarpment and record the gully wall or escarpment slope angle in the gully/escarpment angle field in the stream/gully section of the field data form. If this is a conventional boundary record the slope angle for the first ±20 metres into the standing timber.

Boundary aspect

- Record the direction perpendicular to and away from the stand (reserve) boundary edge. In the case of 2-sided reserve strips the aspect of both boundaries (sides) of the strip are recorded as both sides of the boundary are traversed and treated as separate samples.

Boundary/slope geometry

- U – uphill – the boundary is on the upslope side of the block.
- UE – uphill boundary at the base of an escarpment.
- D – downhill (the boundary is on the downhill side of the opening and the slopes are generally >40%, up to 70%).

- L – lateral (a boundary running roughly perpendicular to the horizontal contour and slopes along within the leave strip or setting edge are generally range from 10 to 40%)
- F – flat or level or undulating
- GE – gully edge (falling boundary runs along the edge of a gully).
- HG – hillslope along gully (the leave strip includes both the gully and a strip of standing timber along the hillslope beside or above the gully. The falling boundary is often 5 to 20 metres away from the edge of the gully. The slopes within the hillslope portion of the leave strip are less steep than those on the gully side.)
- E – Escarpment. Slope angles are generally >70% when this designation is used.
- HE – hillslope along or above a stream escarpment or other definite escarpment. (The leave strip includes both the escarpment and a strip of standing timber along the hillslope beside or above the escarpment. The falling boundary is often 5 to 20 metres away from the edge of the escarpment. The slopes within the hillslope portion of the leave strip are less steep than those on the escarpment.)
- HS – hillslope - used when the boundary is running perpendicular to the contours and the slopes are between 40 and 70%.

Boundary shape

- 1 - concave
- 2 – convex
- 3 – straight
- 4 – complex (irregular)

Influences

- S – possible shelter by an adjacent boundary
- E – possible increased exposure because of an adjacent boundary
- O – possible increased exposure because of the opposite side of the strip edge is a windward boundary
- T – possible shelter by topography
- L – Lake adjacent (i.e., one side of strip or patch, is bounded by a lake)
- W – Wetland adjacent
- P – Plantation adjacent
- N – nominal (nothing obvious)

Harvesting system

- G - Grapple
- T - High lead tower
- H - Hoe
- R - Helicopter
- S - Skyline

Plot type (strata)

- E - External block edge
- P - Patch edge
- WS -'Wide' strip edge > 50 m wide
- PE - Peninsula edge a strip that extends into an opening but is attached to the external boundary
- B – Bulge – a stubby peninsula that is wider than it is long
- S - Strip < 50 m wide – strips have straight edges
- R - Ribbon – have curves
- GE - Group edge
- G - Group – groups are groups of trees 20 to 50 m across
- X - Cluster – groups of trees less than about 20 metres across
- D - Dispersed individuals

Group/cluster/patch shape

- S - Square
- C - Circle
- R - Rectangle
- E - Ellipse
- P - Polymorphic
- T - Triangle
- D – Doughnut (typically polymorphic or irregular with a low area in the center of the group or patch)

Boundary purpose

- R – Riparian - streams
- L – Lake riparian
- T - Terrain stability
- W - Wildlife
- V - Visual
- G – Generic
- S – Wetland

Leave strip width (treated and/or untreated)

- This is the distance in metres from the edge of the riparian reserve zone or management zone (leave area) to the stream or other feature. If the margin or all of the leave area has been treated (e.g. feathered, thinned, topped, pruned) then record the width of this zone in the treated width field. Record the untreated leave strip width in the untreated width field.

Treatment depth (width) and percentage

- Distance in metres that pruning or feathering etc. extends into the stand edge and the approximate percentage of trees treated or removed from the stand edge within that distance.

Fetch Type

- C - Clearcut
- S - Strip(s)
- R - Ribbon(s)
- G - Groups
- X - Clusters
- GX - Groups and clusters
- D - Dispersed individuals
- GD - Groups and dispersed individuals
- XD – Clusters and dispersed individuals
- GXD - Groups /clusters / dispersed individuals
- GDZ – Groups, dispersed individuals and dispersed saplings and/or groups of saplings (Z)
- GXDZ – Groups/ clusters/ dispersed individuals and saplings (saplings = non-merchantable)

Setback distance

- Distance a boundary is setback from the edge of a gully or escarpment.

General topography of area

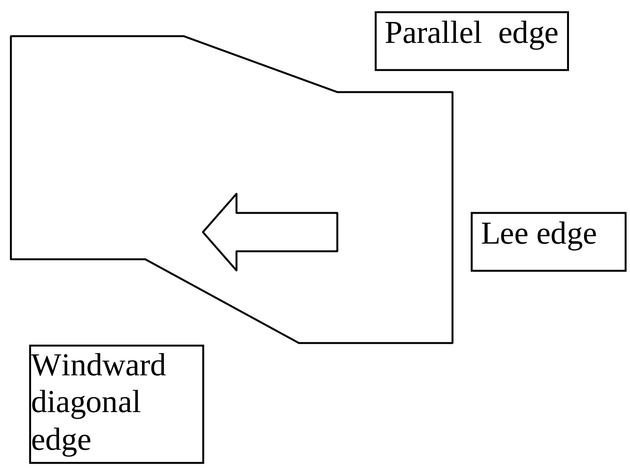
- CP – coastal plain
- LH – low hills (relative relief = 50 – 200 metres), no well defined valleys
- MH – moderate hills (relative relief = 200 – 500 metres), no well defined valleys
- HH – high hills (relative relief = 500 – 1000 metres), no defined valleys
- SV - Shallow well defined valley (relative relief is less than 200 metres)
- MV – Moderately deep, well defined valley (relative relief 200 – 500 metres)
- DV – deep, well defined valley (relative relief 500 – 1000 metres)
- VDV – very deep, well defined valley (relative relief is greater than 1000 metres)
- MVN – narrow (V-shaped), moderately deep, well defined valley
- MVB – broad (U-shaped), moderately deep, well defined valley
- DVN – narrow, deep, well defined valley
- DVB – broad, deep, well defined valley

Boundary exposure (1st, 2nd)

For external boundaries and long-axis exposure for patches/groups

- This is the boundary exposure or orientation relative to the apparent primary and secondary windthrow (wind) orientations recorded for the block (there may be no clear dominance). Windward and lee refer to the standing timber edge (e.g., a stand edge that has a wind blowing directly into it from the 'open clearcut area' is defined as a windward boundary). Make these estimates in the office after all plot data has been collected for a given block. Use the apparent dominant direction of windthrown trees around the perimeter of the block to make this estimate not just the windthrow orientations from a single plot. Be careful not too generalize too much. In some cases, for example if a block straddles a ridge line at the intersection of two valleys (e.g., an east-west valley and a north-south orientated valley), the dominant wind directions may vary from one side of the block to another.

- W – windward edge
- L – lee edge
- P – parallel edge
- WD – windward diagonal
- LD – lee diagonal



Valley axis orientation

Take this measurement from a 1:50,000 scale map so that the general orientation of the valley in the vicinity of the block can be easily seen. Where a block is exposed to two different valley orientations (e.g., a block which straddles a ridge line) then record the valley orientation relevant to each individual plot. This data is evaluated to determine how strongly the orientation of specific valleys influences or does not influence the direction of damaging winds.

- N-S
- E-W
- NW-SE
- NE-SW

Stream name

- Record from the logging plan map

Stream class

- S1 –S6 as per the BC Forest Practices Code

Reserve type

- **RRZ-1**– 1-sided riparian reserve zone (streams)
- **RRZ-2**– 2-sided riparian reserve zone (streams)
- **FRMZ-1 –** 1-sided forested riparian management zone. Usually refers to strips where most larger trees are left but can be a feathered edge where only a few of the larger large trees are left by the fallers. If the riparian management zone is composed only of stumps (e.g. there are no residual trees) then do not record the RMZ as being present.
- **FRMZ-2** – 2-sided forested riparian management zone.
- **WTP** wildlife tree patch
- **GR –** gully reserve

Stream width and depth

- Estimate the stream width and depth in metres at bankfull discharge.

Bed and bank materials (textures)

- c – clay
- z – silt, zs – silt and sand
- s – sand, sg – sand and gravel
- g – gravel, gk – cobbles and gravel
- k - cobbles
- b – boulders, bk –boulders and cobbles, bkg – boulders, cobbles, gravel
- r – rubble
- a – blocky
- R - bedrock

These codes can be used when there is a mixture and/or distinct zones of the above textures/materials.

WT Proximity – proximity of windthrown trees to the stream channel

- N – none apparent - no windthrow reaches the stream
- T – touching - tops of some trees touch and a few windthrown trees may cross the stream
- A – across – a large number of the windthrown trees fall across the stream and most are lying €2 metres above the stream
- B – bank – trees in and along bank are uprooted
- X – trees on both sides of the stream are uprooted

- S – suspended – most windthrown trees are > 2 – 3 metres above the stream
- AX – across and there are uprooted trees on both sides of the stream
- AB – across and uprooted trees along stream bank

Stream Effects

- N – none apparent
- B – limited bank disturbance (estimate % of bank length disturbed: 1%, 2%, 5%, 10%, up to 20%)
- C – channel and stream banks are significantly disrupted (more than 30% of channel is disturbed – estimate % length of channel disturbed).
- S – some sediment delivery to channel visible or very likely
- U – unknown

Figure 3-I. Wind Exposure Index/Wind Exposure Class

Boundary exposure 1		Lee (1)	Lee diagonal (2)	Parallel (3)	Windward diagonal (4)	Windward (5)
	Boundary exposure 2	1	2	3	4	5
Lee	1		**3**	**4**	**5**	**6**
Lee diagonal	2	**3**	**4**	**5**	**6**	**7**
Parallel	3	**4**	**5**	**6**	**7**	**8**
Windward diagonal	4	**5**	**6**	**7**	**8**	**9**
Windward	5	**6**	**7**	**8**	**9**	

Note: Wind Exposure Index = (Boundary exposure 1 rank) + (Boundary exposure 2 rank)

Wind Exposure Index (sum of ranks)	Wind Exposure Class	Wind Exposure Class number
3	Very low	1
4	Low	2
5-7	Moderate	3
8	High	4
9	Very high	5

The wind exposure index (WEI) is a simple, qualitative scoring scheme, developed for the riparian windthrow study, that ranks the expectation that a specific falling boundary segment will be affected by strong winds from more than one direction. The primary and secondary (or co-dominant) windthrow orientations for a block are compared in turn to each specific boundary segment orientation (aspect) to determine the primary and secondary exposure categories for that boundary segment (i.e., lee, windward or an intermediate exposure category). The assumption is made that the post-logging windthrow orientations in a sample block or boundaries in the immediate vicinity indicate the dominant wind directions that may affect a specific boundary segment. A simple ranking matrix is then created that lists boundary exposure categories along the x and y axes, defined as lee through windward and ranks them consecutively (i.e., lee = 1, parallel = 3, windward = 5). The individual rank values are added vertically and horizontally to determine the WEI for specific boundary segments or riparian sample strips. When there is only one windthrow (wind) orientation the WEI can be less than 3.

Appendix IV
Field Data Form Used for Year 2003

Prototype field data sheet for survey of pruned and topped or non-treated edges

- Treatment type (**P**runed, **T**opped, **F**eathered, **N**o treatment)
- Treatment depth (meters)
- Windthrow class (**N**one, **L**ow = 1-10%, **M**oderate 10-20, **MH** = 20-50%, **H**igh >50)
- Windthrow penetration – in meters
- Environmental effects (**L**and**S**lide, **S**treambank, **L**akeside, **P**ark boundary, **CMT**, **B**ear **D**en, **N**est)

Block	Falling corners	Treatment /treatment depth (m)	Windthrow %	Penetration (m)	Effects	Windthrow orientation	Avg Stand Height